AGR 204 Farming System and Sustainable Agriculture (1+1)

Theory :

Unit - I: Cropping System

Cropping systems - Definition - Principles - Concepts - Classification - mono cropping - intensive cropping - cropping systems of India and Tamil Nadu - Interaction between different cropping systems - Cropping system management - Resource management - land, nutrient, water and weed.

Unit - II: Evaluation of Cropping System

Index for evaluation of cropping systems - Land use - yield advantages - Economic evaluation - sustainability.

Unit - III: Farming System

Farming systems - Definition - Principles - Concepts - Enterprises selection and management - interaction between different enterprises with cropping - scope and advantages of Integrated Farming system - Integrated farming system models for different agro eco-systems - interaction between enterprises.

Unit - IV: Evaluation of Farming System

Resource recycling in IFS - Evaluation indicators of integrated farming system - LEISA & HEIA - concepts and principles - Conservation agriculture - principles, concept and scope.

Unit - V: Resource and labour management in farming system

Resource management under constraint situation - Cost reduction strategies in crop production - Non-monetary inputs and low cost technologies - Labour management - farming system and environment.

Practical:

Preparation of cropping scheme - working out input requirements for crops, cropping systems - preparation of calendar of operations for wetland, irrigated upland and dry land cropping system - visit to cropping system experiments - working out indices for evaluation of cropping systems - visit to different units: dairy, goat, poultry, fishery. Mushroom, sericulture and biogas - study on evaluation indicators on farming system - preparation of integrated farming system models for different eco-systems - on farm field visit - analysis of farming system models.

Lecture Schedule

1. Cropping system: Definition, Principles and basic concepts.
2. Classification of cropping system - Mono cropping, intensive cropping, multiple cropping, mixed cropping.
3 Major cropping systems prevailing in India and Tamil Nadu for different agro eco systems.
4. Complementary and competitive interaction in different cropping system - light, nutrient, water and weed.
5. Cropping system management: agronomic requirement for crops and cropping system selection of crops and varieties, tillage and land shaping, plant population and crop geometry.
6. Cropping system management: agronomic requirement for crops and cropping system - water management, soil fertility management and plant protection.
7. Indices for evaluation of cropping system - land use, yield advantage and economics.

8. Farming system: definition, principles and concepts and factors influencing choice and size of enterprises
9. **Mid Semester Examination.**
10. Scope and advantages of integrated farming system.
11. Allied enterprises for wetland, irrigated upland and dryland - selection and management and their interaction.
12. Resource recycling in integrated farming system.
13. Integrated Farming System evaluation indicators.
14. Integrated farming system - models for wetland, irrigated upland and dryland eco system.
15. LEISA and HEIA - principles and concepts and Labour management in integrated farming system.
16. Conservation agriculture and environmental impact of integrated farming system.
17. Cost reduction technologies and non monetary inputs in integrated farming system.

Practical Schedule:

1. Visit to cropping system experiments in wetland.
2. Visit to cropping system experiments in irrigated upland and dryland.
3. Preparation of cropping scheme for wetland and working out input requirement.
4. Preparation of cropping scheme for irrigated upland and working out input requirement.
5. Calendar of operations for wet land and irrigated upland cropping system.
6. Working out indices for evaluating the cropping system - land use, yield advantage.
7. Working out indices for evaluating the cropping system - Economics, sustainability.
8. Visit to dairy, goat and poultry units.
9. Visit to mushroom unit.
10. Visit to sericulture and biogas unit.
11. Preparation of integrated farming system models : wetland eco-system.
12. Preparation of integrated farming system models : irrigated upland and dryland eco systems.
13. Resource recycling in integrated farming system models of different eco systems.
14. Evaluation of integrated farming system models : wetland eco-system.
15. Evaluation of integrated farming system models : irrigated upland and dryland eco systems.
16. On-farm visit to cropping fields and integrated farming system units.
17. **Practical examination**.

References:

1. Palaniappan, SP and K. Sivaraman.1996. Cropping systems in the tropics Principles and management.
2. New Age International (P) Ltd., New Delhi.
3. Jayanthi, C. Devasenapathy, P and C. Vennila. 2007. Farming Systems. Principles and practices. Satish Serial Publishing House.Delhi.
4. S.C. Panda. 2003. Cropping and Farming Systems. Agrobios Publishers. Jodhpur. Jana, B.L. 2014. Farming Systems. Agrotech Publishing Academy, Udaipur Shagufta. 2015. Cropping and Farming Systems. APH Publishing Corporation

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1. www.agriinfo.in, www.fao.org, www.agritech.tnau.ac.in

Lecture 1. CROPPING SYSTEM AND SYSTEM APPROACH: PRINCIPLES, CONCEPTS AND IMPORTANCE

- Agriculture system today becomes manipulations of ecosystems for human gains.
- Yield and profit maximization approach has led to serious environmental, ecological, economical and social problems.
- Human society today is dominated by rapid technological and political innovations, summed by terms like globalization or information technology.
- The disseminated information is making more conscious on the quality of food and environmental consequences.
- A cropping systems adopted on a farm has more obvious and detectable social, ecological, economical and environmental implication.
- So, it is necessary to understand the principles and concepts underlying the entire ecosystem to have profitable, resource efficient and environmentally sound ecosystem.

Principles and Concepts

- Systems approach which is extensively employed in business and industry is being introduced in crop production also with a view to use the available resources effectively and to increase the returns to the farmer.
- Accordingly crop production research has been reoriented as cropping system research in the country.
- Agronomic research increase the resource use efficiency for a given crop, cropping systems and cropping pattern as a variable with a view to use the available resources more efficiently.
- Hence, the objective of any cropping system is to increase the efficiency or utilization of resources – land, water and solar radiation.
- The efficiency is measured by the quantity of produce obtained per unit resource in a unit time.
- The productive base of a cropping system is the crop growth and yield. Crop yield (Y) can then be considered as a function (f) of management factors (M) and environment (E).

  $\bar{Y} = \bar{f}\,(\overline{M}, \overline{E})$

- For the cropping systems researcher, management (M) includes the type and arrangement of crops in time and space (cropping pattern), choice of variety, methods of stand establishment, pest management and harvest.
- Environment (*E*) is composed of land and climate related variables as rainfall, irrigation, soil, solar radiation and temperature and availability of resources as power, labour and cash. Economic factors such as cost of inputs, price of produce, interest rates, etc., should be included in the environment components.
- Hence, it is evident that the management term is treated as a variable and the environment term as invariant.

- A cropping system researcher studies the interaction between *M* and *E* and seeks to determine how he should vary his cropping pattern, *M* to optimize the returns for different production environment. In this concept, *E* becomes a fixed constraint and the interaction between *E* and *M* gets merged with *M*.
- On this basis, cropping system can be defined as cropping pattern and its management to derive benefits from a given resource base under specific environmental condition. The term cropping systems can be applied to a farm or a region.
- Cropping system is location specific and to develop an alternate cropping system for a location, the prevailing environment of that location should be clearly understood.
- In suggesting an alternative cropping system for a location, it is generally assumed that the available physical resources are not fully exploited and hence by intensification of cropping, this lacuna can be removed.
- The crop intensification techniques include intercropping, relay cropping, sequential cropping and ratoon cropping.

Importance of Cropping System

The cropping system research to date has adequately demonstrated the following potentials for adopting cropping system as a development strategy in contrast to monoculture

- Improved stability of food supply throughout the year
- Increased total food production per land unit per year, generally accompanied by an increase in total income for the farmer
- Sustaining the soil health
- Improved distribution of income throughout the year
- Increased total employment of labour throughout the year
- Improved nutrition for the farm family from crop diversification
- The use of cropping system as a strategy for increasing productivity and the income of small farmers

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Lecture 2. CROPPING SYSTEMS : TERMS AND DEFINITIONS CLASSIFICATION OF CROPPING SYSTEM - MONO CROPPING, INTENSIVE CROPPING, MULTIPLE CROPPING, MIXED CROPPING

System

- Arrangement of components which process input into output.
- Each system consists of boundaries, components, interactions between components, inputs and outputs

Crop System

Arrangement of crop population that transfer solar energy, nutrients, water and other inputs into useful biomass. Crop system is a sub system of cropping system

Eg. Maize crop system, Rice crop system, Sugarcane crop system

Cropping System

The cropping patterns used on a farm and their interaction with farm resources, other farm enterprises, available technology and environment (physical, biological and socio economic) which determine their make up.

Cropping Pattern

The yearly sequence and spatial arrangement of crops or crops and fallow on a given area.

Eg. Rice-Rice- Pulses
Groundnut- Maize- Fallow
Fingermillet- Cotton- Pulses/Fallow
Chillies- Maize- Green manure

Crop Rotation

The repetitive cultivation of an ordered succession of crops (or crops and fallow) on the same land. One cycle may several years to complete.

Eg. Rice- Rice-Pulse (one year rotation)
Ground nut- Maize- Fallow- Green gram- Sunflower- Fallow (2 yr. rotation)
Sugarcane- Sugarcane ratoon- Rice- Maize-Green manue (3 yr. rotation)

Mono cropping

The repetitive growing of the same crop on the same land.

Eg. Growing rice after rice in the same field season after season

Multiple Cropping

The intensification of cropping in temporal and spatial dimension; growing two or more crops on the same field in one year.

Double, Triple and Quadruple Cropping

Growing two, three and four crops, respectively, on the same land in a year in sequence

Sole cropping

One crop variety grown alone in pure stand at normal density.

Intercropping

Growing two or more crops simultaneously on the same field; crop intensification is in both temporal and spatial dimensions; there is intercrop competition during all or part o crop growth. Intercropping systems tend to be low input, risk reducing under dry farming situations for cropdiversification and fulfillment of subsistence objectives. At higher input levels it will be able to necessary to reevaluate and recombine various activities.

Eg. Groundnut + Redgram + Castor
Cotton + Black gram/green gram
Sorghum + Redgram

Mixed Intercropping

Growing two or more crops simultaneously with no distinct row arrangement. Also referred to as mixed cropping. The seeds of the crop varieties are mixed in desired proposition, sown and incorporated.

Eg. Grass legume mixture; Mixing the seeds of sorghum and cowpea in 5:1 ratio and broad casted.

Row Intercropping

Growing two or more crops simultaneously where one or more crops are planted in rows; often referred to as row intercropping.

Eg. Sorghum in paired rows intercropped with one row of cowpea
Planting 1 row of red gram for every 10 rows of groundnut

Strip Intercropping

Growing two or more crops simultaneously in different strips wide enough to permit independent cultivation but narrow enough for the crops to interact agronomically. Normally followed in sloppy lands and in soils prone for erosion.

Eg. Wheat and Bengal gram in alternate strips of 5-10 m

Relay Cropping

Growing two or more crops simultaneously during the part of the life cycle of each. A second crop is planted after the first crop has reached its reproductive stage of growth but before it is ready for harvest.

Eg. Broad casting black gram or green gram in the standing rice crop about 7-10 days before its harvest

Sequential Cropping

- Growing two or more crops in sequence on the same field in an year

- The succeeding crop is planted after the preceding crop has been harvested
- Crop intensification is only in the time dimension
- There is no intercrop competition.
- Sequential cropping systems are customarily encountered where resource endowments, especially water availability.
- The sequential cropping utilize higher inputs and income maximization is a more important objective than in the case of intercropping.

Ratoon cropping

The cultivation of crop regrowth after harvest, although not necessarily for grain.

Eg. Sorghum ratoon, sugarcane ratoon, fodder grass ratoon

Farming System

It is decision making unit comprising the farm household, cropping and livestock systems that transform land, capital (external inputs) and labour (including genetic resources and knowledge) into useful products that can be consumed or sold. The farming systems comprises the cropping system(s), the livestock system(s) and the farm household (Fresco and Westphal, 1988).

Agroforestry

It is a collective name for land use systems in which woody perennials (trees, shrubs, etc.,) are grown in association with herbaceous plants (crops, pastures) and/or livestock in a spatial arrangement, a rotation or both, and in which there are both ecological and economic interactions between the tree and non-tree components of the system.

Alley Cropping

It is an agroforestry system in which food crops are grown in alleys formed by hedgerows of trees and shrubs, preferably, legumes. The hedgerows are cut back at planting and periodically pruned during cropping to prevent shading and to reduce competition with the associated food crops. The hedgerows are allowed to grow freely to cover the land when there are no crops. When this concept is extended to include livestock by using a portion of the hedgerow foliage for animal feed, it is called alley farming (Kang et al.,1990).

Cropping index

The number of crops grown per annum on a given area of land multiplied by 100

TERMINOLOGIES IN CROPPING SYSTEMS

Arboriculture: Cultivation of tree species for fruits, gums, mats, etc.

Agri-silviculture: It is the conscious and deliberate use of land for the concurrent production of agricultural and forest crops.

Agricultural ecosystem or agro-ecosystem: It is composed of the total complex of the crops and animals in an area together with overall environment and as modified by management practices.

Agri-silvi-pastoral system: A system in which land is managed for the concurrent production of agricultural and forest crops and for the rearing of domesticated animals. This system is, in fact a combination of agri-silviculture and the silvi-pastoral system.

Agro – ecology: The study of the relationship of agricultural crops and environment.

Agrostology: A branch of science which deals with the study of grasses, their classification management and utilization.

Annidation: Complementary use of environmental resources by intercrop components.

Arboriculture: Cultivation of woody plants, particularly those used for decoration and shade.

Blind cultivation: Cultivating with a harrow weeder, rotary weeder or there implements to kill weeds before a seeded or planted crop has come up.

Bush-fallow system: Farming systems in which the natural regeneration of self-propagated plants in successional community is the restorative agent in respect of nutrients, organic matter, water conservation and microclimate. Crop plants are grown on patches cleared by felling of trees and/or burning of grasses and herbs, fallow succession dominated by woody shrubs and grasses.

Co-operative better farming: A type of co-operative farming where the land is not pooled and the cultivation is carried on by each farmer separately. A member is free to form his own way of farming except in respect of the purpose for which he has joined the society e.g. for irrigation, purchase of seed or marketing of produce etc.

Co-operative collective farming: A type of co-operative farming where in the land is owned by the society and cultivation is carried out jointly. The members work on the land under the direction of a managing committee. The profits are paid to the members in proportion to the work and capital contributed by each member. The right or share of individual member in the land is not recognized.

Co-operative farming: Co-operative farming means a system under which all agricultural operations or part of them are carried out jointly by the farmers on a voluntary basis, each farmer retaining right in his own land. The farmers pool their land, labour and capital. The land is treated as one unit and cultivated jointly under the direction of on elected management person. Apart of profit is distributed by each farmer and the rest of the profit is distributed in proportion to the wages earned by each farmer.

Co-operative joint farming: In this type of farming, the land of members is pooled for joint cultivation. The ownership of each member over his own land is recognized by payment of a dividend in proportion to the value of his land. The members work under the direction of the managing committee and each member receives for his daily labour.

Co-operative tenant farming: A type of co-operative farming wherein the land is held by the society and not by the members independently. The land is then divided into plots which are leased out to members. The society arranges for agricultural requirements e.g. credit, seeds, manures, marketing of the produce etc. Each member is responsible to the society for payment of the rent of his joint plots. He is at liberty to dispose off his produce in such a manner as he likes.

Commercial farming: The type of farming where capital input is high and the production is marked and profit oriented.

Conservation cropping: A way of farming that aims to maximise the protection against erosion that can be achieved through soil and crop management for sustained farm productivity.

Contingency cropping: Contingency cropping is growing of crops in aberrant situations like drought and floods. It aims at partial mitigation of misery by producing some food, feed and fodder to encounter emergency conditions.

Contour farming: A method of cultivation wherein operations including sowing are carried out along the contour. It reduces run-off, conserves more moisture and increases crop yield.

Contour strip cropping: The cultivation practice involving growing of a soil exposing and erosion permitting crop in strips of suitable width alternating with strip of soil protecting and erosion-resisting crops, along with the contours.

Crop ecology: The branch of ‘plant ecology’ which deals specifically with the study of the interrelation amongst crop plants and environment including management practices.

Crop ecosystems: Cropping systems ranging between monoculture and multi-species culture of field and garden crops, single or combination and their relation to environment conditions and management practices.

Diversified farm: A farm on which no single product or source of income equals as much as 50% of the total receipt and no such farm the farmer depends on several sources of income.

Dry farming or dry land farming: The practice of crop production entirely with rain water received during the crop season or on conserved soil moisture in low rainfall (< 800 mm) areas of arid and semi-arid climate and the crops may faced mild to very severe stress during their life cycle.

Energy farming: A concept involving the farming of fast-growing plants or trees for the purpose of providing biomass that can be used directly as fuel or converted into other forms of fuel or energy products.

Farm management: The branch of agricultural economics which deals with the business principles and practices of farming with an abject of obtaining the maximum possible return from the farm as a unit under a sound farming programme.

Farm planning: A process involving many decisions to be taken in respect of kinds of crops to grow, rotations, mixtures, soil and water conservation practices to be followed and building bullocks, machinery purchase etc.

Farming system research: It is highly location-specific research which is multi-and interdisciplinary in nature and uses whole farm approach for improved technologies to enhance and stabilize agricultural production. The research strategy includes base data analysis, on-centre research and on-farm research. This is the final evaluation of system in the real world situation of the farmer.

Jhum cultivation: The slash-and-burn type of shifting cultivation in the hill tracts of Bangaladesh and Assam.

Ley farming: A rotation of arable crops requiring annual cultivation and artificial pastures occupying field for two years or longer.

Mechanized farming: It is the farming in which machine-drawn implements are used for the reduction of labour requirement or elimination of manual work, timeliness of operations and improved quality of husbandry, resulting in higher output and better quality of produce for increased profit.

Natural farming: It is a system of alternative agriculture in which the plants are grown as natural entities without manipulation of soil. It is a system of farming which uses no machines, no prepared fertilizers and no chemical but yields normal harvests.

Opportunity cropping: The practice of placing primary emphasis on the use of stored soil moisture while determining whether or not to establish a crop.

Organic farming (biological husbandry): It is a agricultural production system which avoids or largely excludes the use of synthetically compounded fertilizers, pesticides, growth regulators and livestock feed additives. To the maximum extent feasible organic farming systems rely upon crop rotations, crop residues, animal manures, legumes, green manures, mineral bearing rocks and aspects of biological pest control to maintain soil productivity and tilth to supply plant nutrients and to control insects, weeds and other pest

Outer crop or guard crop or border crop: The crops which are grown around the field boundaries in narrow strips with twin objectives of protecting the main crop from stray cattle and producing livestock feed and/pr seed are called outer or guard crops, e.g. Sesbania or Leucaena on boundaries of field/plantation crops and castor around spring-planted sugarcane.

Paira crop (utera): It is a crop sown broadcast in the standing crop of lowland rice before its harvest where the residual moisture is used for the establishment of utera crop, e.g. lathyrus, gram, lentil, green gram, etc. in standing crop of rice.

Pitcher farming: A practice in dry farming where crop is irrigated through small holes made in the bottom of earthen pitcher. The practice is generally used for wider spaced plants.

Rainfed farming: Growing of field crops entirely with rain water received during crop season (rainfall usually > 800 mm) under humid and sub-humid climates and the crops may face little or no moisture stress during their life-cycle

Recession farming (diara land farming): It is a system in which crops are planted in flooded areas as the rainy season ends and water recedes. This system takes advantage of thoroughly saturated soil profile and also has the advantage of silt and nutrients left behind by flood water.

Shifting cultivation: The practice of cultivating clearings scattered in the reservoir or natural vegetation (forest or grass woodland)and of abandoning them as soon as the soil is exhausted, and this includes the practice of shifting homesteads in order to follow the cultivator's search for new fertile land.

Subsistence farming: It is farming enterprise which provides food and commodities just sufficient for the farming family, and there is no surplus to sell.

Sustainable agriculture: Sustainable agriculture should involve the successful management of resources for agriculture to satisfy changing human needs while maintaining or enhancing the quality of the environment and conserving natural resources.

Lecture 3. MAJOR CROPPING SYSTEMS PREVAILING IN INDIA AND TAMIL NADU FOR DIFFERENT AGRO ECO-SYSTEMS

INDIA

Promising rice-based cropping systems in India

Promising rice-based cropping systems with high productivity and intensive land use for diverse-climatic situations of India have been identified in multi-locational experiments under Cropping Systems Research Project.

Systems	Region
Rice – Indian mustard	Kashmir valley
Rice – wheat – sorghum (Fodder)	Jammu region
Rice – wheat- green gram	Punjab, Haryana, U.P
Rice – Mustard	North Konkan
Rice – field bean	South Gujarat
Rice – groundnut	South Karnataka
Rice – black gram/sesame/cotton	Thanjavur, Tamil Nadu (Old Cauvery delta)
Rice – groundnut	Thanjavur, Tamil Nadu (New Cauvery delta)
Rice – mustard	Assam
Rice – wheat – jute	West Bengal
Rice – groundnut	Coastal Andhra Pradesh and Orissa
Rice – green gran	Eastern Madhya Pradesh

Crop sequences under irrigated upland conditions

Under irrigated uplands (garden lands) depending upon the water availability or irrigation potential, more than two crops can be grown in a year, Crop sequences and their production potential have been tested under different agro climatic conditions. At Delhi, four crop sequence of green gram – maize – potato – wheat gave the highest production of 13.6 t/ha. However, three crop sequence of green gram – maize – wheat was found to be the most ideal for the small and marginal farmers.

Crop sequences and their production potential

Crop sequences		Total production (q/ha)
New Delhi		
Two crops	Maize –wheat	90.1
Three crops	Green gram – maize – wheat	97.7
	Green gram – pigeon pea – wheat	68.8
	Green gram –pearl millet – wheat	92.9
Four crops	Green gram – maize – potato – wheat	135.9
	Green gram – maize – toria – wheat	112.8

State	Crop sequences	Duration (days)	Grain	Yield (q/ha)	
				Fodder	Vegetable

Himachal					
Pradesh	Soybean – wheat	323	77	-	-
	Soybean –potato	283	34	-	72
	Maize –wheat	299	65	-	-
Haryana	Pearl millet- wheat - cowpea (f)	323	83	63	-
	Maize –wheat- Cluster bean (f)	323	82	103	-
	Pearl millet-wheat –maize	232	81	126	-
Uttar	Maize –wheat-Pearl millet (f)	301	108	316	-
Pradesh	Sorghum –wheat-green gram	306	63	-	-
	Sorghum –wheat- Cowpea	313	59	-	-
	Pearl millet-'Wheat – green	339	35	-	-
Rajasthan	gram	295	22	-	-
	Green gram-Wheat – green				
	gram	323	70	-	-
Madhya		325	70	-	-
Pradesh	Maize – wheat- Cowpea				
	Maize – wheat- green gram				

In multi – location experiments, under Cropping Systems Research Project, promising cropping systems with high productivity as well as intensive land use for diverse agro climatic situations have been identified

Potential cropping systems for different agro climatic situations

Region	System
Western Haryana	Cotton – wheat
Rajasthan	Groundnut – wheat
Madhya Pradesh	Soybean – wheat
North Gujarat	Pearl millet – mustard
Sourashtra region – Gujarat	Cotton – groundnut
Western Maharashtra	Sorghum – wheat
Western Maharashtra	Groundnut - wheat
Marathwada region of Vidarba region	Cotton – groundnut
North Karnataka	Sorghum – bengalgram
South Karnataka	Cotton - groundnut

Cropping systems in dry lands

Normally only one crop is grown under dryland condition and cultivation is restricted during the rainy season. However, the intensity of cropping can be increased through sequential or intercropping, depending on the rainfall and moisture storage capacity of the soil.

Cropping pattern with varying rainfall and soil moisture storage capacity

Rainfall (mm)	Storage capacity of soil (mm)	Cropping pattern
350 – 625	100	Single crop in *kharif*
650 -750	100	Intercropping can be attempted
780 -900	150	Sequential cropping is possible
900 - above	200	Sequential cropping is possible

Choice of crops: Selection of a suitable crop and genotype is important to get higher yield in dry farming conditions. Deep rotted crops extract moisture from the deeper layers and they also have slow rate of transpiration. Leguminous crops are very well adopted for rainfed conditions because their root systems. Among the cereal, barley ability to harvest moisture from deeper layers than wheat. Moisture loss from the plant surface is less in barley. Similarly linseed has greater ability to trap soil moisture under water scarce situation.

Cropping systems for dry lands

Important factors such as total rainfall, soil type and water availability have to be considered while practicing a particular cropping pattern in a place/region. Cropping system for different regions as suggested from the results of **AICARP** are given in the following table.

Cropping systems for different region of India under dry lands

Regions/soil type	Crops	
	Kharif	*Rabi*
Northern Region		
Samba (Jammu)	Maize	Wheat
	Green gram	Barley
	Cowpea	Wheat
	Sunflower	Wheat/barley
	Groundnut	Barley
	Pearl millet	Bengal gram
Punjab	Sorghum	Wheat
	Maize	Wheat /Potato / Barley
Hisar (Haryana)	Pear millet	Cluster bean /Chickpea
Arid soils (Sierozemic soils)	(Mono cropping is the rule)	
Central Region		
Dehra Dun	Maize	Wheat
(Uttar Pradesh)	Rice (upland)	Wheat/ Bengal gram
Agra (Uttar Pradesh)	Gram	Mustard
Entisols (Alluvial soils)	Pearl millet	Chickpea/Barley

Varanasi (Uttar Pradesh)	Sesame	Chickpea/Mustard
Entisols (Alluvial soils)	Bengal gram	Barley/Mustard
	Rice	Chickpea / Mustard
	Pearl millet	Chickpea / Mustard
Eastern Region		
Ranchi (Bihar)	Rice	Chickpea / Linseed/Barley
Alfisols and related red soils	Maize	Rapeseed / Bengal gram
Bhubaneswar (Orissa)	Rice	Linseed / Mustard
Alfisols and related red soils	Finger millet	Horse gram
	Maize	Horse gram
Rewa region (M.P)	Rice	Chickpea / Lentil
Vertisols and black soils	Sorghum	Bengal gram / wheat
Jhansi region (M.P)	Green gram	Wheat /Chickpea
Vertisols and related black	Sorghum	Bengal gram
soils	Pearl millet	Bengal gram
	Black gram	Safflower / Chickpea
	Sesame	Bengal gram
Indore (M.P)	Maize	Chickpea
Vertisols and related black	Soybean	Safflower
soils	Soybean	Wheat
Western Region		
Udaipur (Rajasthan)	Green gram	Safflower
(Vertisols and related black	Sorghum	Bengal gram
soils)	Pearl millet	Bengal gram
	Maize	Wheat
	Black gram	Wheat
	Sunflower	-
Anand (Gujarat)	Pearl millet	Wheat
	Pigeon pea	-
Akola (Maharashtra)	Castor	-
Vertisols and related black	Sunflower	-
soils	Green gram	Safflower
Sholapur / Maharashtra	Sorghum	Safflower
Southern regions		
Anantapur (AP)	Green gram	Safflower
	Pearl millet	Bengal gram
	Black gram	Sorghum
Mono-cropping is generally adopted		
Hyderabad	Sorghum	Safflower / Horse gram
Alfisol	Pearl millet	Cowpea / Black gram
Bijapur	Black gram	Sorghum

Vertisols	Green gram	Pearl millet
Bangalore (Karnataka)	Cowpea	Pearl millet / Sorghum
Alfisols		
Mysore (Karnataka)	Pearl millet	Cowpea
	Sorghum	Horse gram
	Sorghum	Green gram / Black gram
	Green gram	Sorghum / Safflower
Bellary (Karnataka)	Cowpea	Finger millet
	Cowpea	Chilli
	Groundnut	Sorghum
	Setaria	Safflower
	Pearl millet	Cotton
Kovilpatti (TN) – rainfed	Cotton	Sorghum
vertisols	Black gram	Bengal gram
		Safflower
	-	Cotton + black gram , Sorghum, Pearl millet, Cowpea, Horse Gram, Chilli

Cropping System for Tamil Nadu

Districts	**Garden land**	**Wet land**	**Dry land**
Kancheepuram	Rice-Veg (Aug-Jan) (Jan-Sep)	Rice-cumbu (Sep-Jan)(May-July)	Rice (Sep-Dec)
Thiruvallur	Vegetables (Feb-May)	Semi dry rice (Sep-Jan)	Ground nut+red gram (Sep-Jan)
Vellore	Cane-ratoon (Dec-Jan) 2 yr rotation Banana-banana 2 yr rotation	Ground nut – rice -rice (Jan-Sep)(June-Sep)(Oct-Jan)	Ground nut+red gram (June-Oct)
Thiruvannamalai	Rice- Ground nut-cumbu (Aug-Jan)(Jan-Apr) (May-July)	Rice- Ground nut (Aug-Jan)(Jan-Apr)	Groundnut-pulses (June-Sep)(Oct-Nov)
Cuddalore	Rice-Rice (June-Sep)(Dec-May) Tapioca+ Ground nut (Oct-Aug)	Rice-Rice-Pulses (June-Sep)(Oct-Jan)(Jan-May) Rice-Pulses (Aug-Feb)(Feb-May)	Cumbu-Groundnut/pulses (June-Sep)(Oct-Jan)
Villupuram	Rice-Rice (Aug-Jan)(Jan-May) Rice-Rice-fallow/Pulses (Aug-Jan)(Jan-May) (June-Aug)	Rice-Pulses (Aug-Jan)(Feb-May)	Groundnut-pulses (June-Oct)(Nov-Feb)
Tanjore	Rice/Groundnut-Pulses (June-Sep)(Oct-Nov)	Rice-Rice-Pulses/sesame (June-Sep)(Sep-Jan) (Jan-May)	Groundnut/pulses (Oct-Nov)
Nagapattinam	Coconut groove	Rice-Rice-Pulses (June-Sep)(Sep-Feb)	Groundnut/pulses (Oct-Nov)

		(Feb-May)	
Thiruvarur	Coconut groove	Rice-Rice-Pulses (June-Sep)(Sep-Feb) (Feb-May) Rice-Pulses (Sep-Jan)(Jan-May)	Groundnut/pulses (Oct-Nov)
Trichy	Rice - Groundnut / sorghum (Aug-Dec)(Dec-Mar) Banana-Rice 2 yr rotation	Rice-Rice-Pulses/sesame (June-Sep)(Oct-Jan)(Feb-Apr) Rice-Pulses/sesame (Aug-Jan)(Feb-Apr)	Red gram+ Groundnut (Aug-Dec) Cotton/Chilli (Aug-Dec) Millet-Horse gram (Oct-Jan)
Karur	Rice/Chillies-Millets/Oil Seeds (Aug-Jan)(Feb-May)	Groundnut- Rice- Millets (June-Sep)(Sep-Jan)(Feb-May) Rice-Rice-Pulses (June-Sep)(Oct-Feb)(Feb-Apr)	Sorghum/Groundnut + Red gram (June-Sep)
Perambalur	Cotton + Onion-Sorghum (Oct-Jan)(Feb-Apr)	Rice- Cotton (Aug-Jan)(Feb-May)	Sorghum/ Cotton/ Pulses (Oct-Jan)
Pudhukottai	Banana-Banana (July-June) 2 yr rotation Sugarcane+Soybean-Ratoon (Dec-Jan) 2 yr rotation	Rice-Pulses/sesame (Aug-Jan)(Feb-Apr)	Sal ragi-Varagu (July-Dec)(Sep-Jan)
Madurai	Cotton - Sesame / Chilli / Pulses (Feb-June)(July-Jan) Rice-Banana 2 yr rotation (Aug-Jan)(Feb-Nov)	Rice-Rice-Pulses/sesame (June-Sep)(Oct-Jan)(Jan-May) Rice- Sugarcane/Banana (Aug-Jan) rotation	Cotton/Groundnut +Pulses (Oct-Feb)
Theni	Sugarcane-Ratoon (Dec-Jan) 2 yr rotation Cotton-Maize (Oct-Feb)(Mar-May)	Rice-Rice-Pulses (June-Sep)(Oct-Jan)(Feb-Apr) Green manure- Rice-Rice (Feb-Apr) (June-Sep)(Oct-Jan)	Sorghum + Red gram Maize/ Sorghum (Oct-Feb)
Dindigul	Rice- Cotton-pulses (Aug-Jan)(Feb-June)(July-Aug) Sugarcane-Ratoon 2 yr rotation	Rice-Pulses (Aug-Jan)(Sep-May)	Sorghum/Cumbu (Oct-Jan) Hill banana
Ramanathapuram	Rice- Cotton/pulses (Sep-Jan)(Feb-Apr) Sugarcane-Ratoon 2 yr rotation	Rice-Pulses (Sep-Feb)(Feb-May)	Rice / Chilli / Pulses / Groundnut (Sep-Jan)
Sivagangai	Sugarcane-Ratoon 2 yr rotation Groundnut- Rice-Pulses (June-Sep)(Sep-Jan)(Feb-Apr)	Rice-Pulses (Aug-Jan)(Feb-May)	Groundnut + Red gram (Oct-Jan)
Vridhunagar	Chilli-Cotton	Rice-Rice-Pulses	Groundnut -Coriander

	(Sep-Feb)(Feb-Aug) Cotton- Cumbu (Feb-Aug)(Sep-Jan)	(June-Sep)(Oct-Feb)(Mar-May)	(Oct-Jan)(Jan-Mar)
Thirunelveli	Rice-Pulses (Oct-Feb)(Mar-May) Sugarcane/ Banana 2 yr rotation	Rice-Rice-Pulses/fallow (June-Sep)(Oct-Jan)(Feb-May)	Sorghum /Groundnut / sesame (Oct-Nov)
Thoothukudi	Cotton-Groundnut (Sep-Mar)(Apr-June) Chilli-Cotton (Sep-Feb)(Feb-Aug)	Rice-Rice-Pulses/sesame (June-Sep)(Oct-Jan)(Feb-Apr) Banana-Rice-Pulses/sesame (June-May)(Jan-Sep)(Oct-Jan) 2 yr rotation	Cotton+Black gram (Oct-Feb) Coriander/Sunflower/ Fodder sorghum (Nov-Jan)
Salem	Tapioca+ Groundnut (May-Feb) Cotton- Sorghum (Aug-Feb)(Feb-Apr)	Rice- Groundnut (Oct-Jan)(Feb-May)	Groundnut + Redgram / castor (July-Jan)
Namakkal	Tapioca+ Groundnut (May-Feb) Cotton- Sorghum (Aug-Feb)(Feb-Apr)	Rice- Groundnut (Oct-Jan)(Feb-May)	Groundnut + Redgram / castor (July-Jan)
Dharmapuri	Rice-Ragi/Tomato/ Groundnut (June-Oct)(Nov-Apr) Veg-Veg-Veg (June-Oct)(Nov-Jan) (Feb-May)	Rice/Groundnut- Rice-Ragi (June-Oct)(Nov-Mar)(Apr-June)	Groundnut/Ragi - Horse gram (June-Oct)(Nov-Jan)
Coimbatore	Sorghum+Cowpea – Ragi - Cotton (Mar-May)(June-Aug) (Aug-Oct)	Maize- Rice- fallow (June-Sep)(Oct-Jan) Rice-Rice (Apr-Aug)(Oct-Feb) Cane-Cane (June-Mar)(Apr-Sep)	Sorghum /RainfedTomato/ Bengal gram (Oct-Jan) Groundnut/Fodder sorghum (Apr-June)(Sep-Dec)
Erode	Cane-Ratoon 2 years Turmeric-Rice (May-Nov)(Nov-May)	Rice-Rice- Rice /fallow (June-Sep)(Oct-Jan)(Feb-May) Rice- Cotton (Aug-Jan)(Feb-May)	Sorghum/Groundnut/ Pulses (June-Sep)
The Nilgris	Veg-Veg-Veg (June-Sep)(Oct-Dec)(Jan-Mar)	-	RainfedPotato/Tea/ Fruit trees
Kanyakumari	Tapioca+Banana (June-May)	Rice-Rice (June-Sep)(Sep-Mar) Turmeric -1 year rotation	Groundnut+ Pulses (June-Sep)(Oct-Jan)

Lecture 4. COMPLEMENTARY AND COMPETITIVE INTERACTION IN DIFFERENT CROPPING SYSTEM – LIGHT, NUTRIENT, WATER AND WEED

Interaction between component crops

In intensive cropping, crops are grown in association (intercropping) or in sequence (sequential cropping). In such situations there is possibility of interaction between the component crops. The interaction is mainly due to response of one species to the environment as modified by the presence of another species. Interaction may be able to competitive, non-competitive and complementary. If the crops are grown in association and the growth of either of the concerned species is not affected, such type of interaction is called as non-competitive interaction or interference. If one species is able to help the other it is known as complementary interaction. e.g. supply of N fixed by the legumes to the associated non-legumes. (This is otherwise known as annidation). One species may have greater ability to use the limiting factor and will gain at the expense of the other. This is called as competitive interaction or interference. Interaction may also occur in some other manner by way of producing toxic substances and affecting the establishment and growth of the associated species. This is called allelopathy.

Interactions in intercropping

Factors such as moisture, nutrient, light and CO_2 are required for plant growth. In mixed or intercropping situations, the component species compete for the growth factors. The close proximity of species causes sub-optimal utilization of the growth factors and hence there is inequitable distribution of resources among the plants. Generally competition will develop between two components or within the components. The nature of such competition may vary depending on the density and proportion of each component and planting pattern.

Interactions in sequential cropping

In sequential cropping, sole crops are grown in succession. Hence, competition for light, water and nutrients as found in mixed cropping does not occur. In relay cropping, a short span of overlapping occurs between two crops in sequence. Hence the relay sown crop at the seedling stage may have competition for light from the standing crop. Such type of competition may be minimized by proper choice of crops and varieties and adjustment of time and method of planting.

In intensive multiple cropping involving two or more crops in sequence, the main adjective is to harvest as much solar energy per unit area per unit time as possible. In rice based cropping system, the solar energy use efficiency ranged from 1.58 to 2.02% of PAR in Uttar Pradesh. In Coimbatore, the efficiency ranged from 0.82 to 1.77% or PAR for the whole year in cotton based system. Inclusion of a C_4 plant in the summer increased the efficiency.

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 crop and carry-over effects of fertilizer applied to the 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. Introduction of pulses as summer crops results in improved yield of rice in *kharif* season.

Interactions for moisture and nutrients

Competition for moisture and nutrients may result in two types of effects on the less successful or suppressed component. First, the roots to this component may grow less on the sides towards plants of aggressive component. Secondly, plants affected by competition for soil factors may have increase root/shoot ration. The aggressive component generally absorbs greater quantity of nutrients and soil moisture. In legume and non-legume combination, the latter takes up large amount of P, K and S. As a result, the legume may show deficiency of these nutrients. Such effects, however, may be able to mitigated by appropriate fertilizer application. Among intercrops, sorghum and pearl millet are more competitive in extracting nutrients. Generally the intercropped stands remove greater amount of nutrients than sole crop stands.

Interactions for light

Intercropping can increase light interception by as much as 30-40%. When one component is taller than the other in an intercropping system, the taller components intercept most of the solar radiation. The pattern of light interception also varies according to the age of the crop. Light transmission by coconut is only about 20% at the age of 8-10 years and this remains almost constant till about 25 years of age. Subsequently the percentage light transmission increases progressively as the canopy coverage of ground decreases. When the palms are at about 40 years of age light transmission increases to about 50%. In an intercropping situation where the component crops have different growth durations, the peak demand for light would occur at different times. For example, in maize + green gram intercropping, the peak light demand for maize occurs at 60 days when green gram is ready for harvest. In such combinations, competition for light is less among the component crops and there is greater light use in intercropping than in pure stands. In general, the component crops under intercropping situations are grown in such a way that competition for light is minimized. Proper choice of crops and varieties, adjustment of planting density and pattern are the techniques to reduce competition and increase the light use efficiency.

Allelopathy

Allelopathy is any direct or indirect harmful effect that one plant has on another through the production of chemical substances that escape into the environment. Some crops may be unsuitable to be grown as intercrops because they may produce and excrete toxins into the soil which are harmful to the associated components. Allelo-chemicals produced from the leaves of *Eucalyptus globules* drastically reduce the germination of mustard sown underneath.

Annidation

Annidation refers to complementary interaction which occurs both in space and time.

Annidation in space: The canopies of component crops may occupy different vertical layers with taller component tolerant to strong light and high evaporative demand and the shorter component favouring shade and high relative humidity. Multi-storied cropping in coconut and planting shade trees in cocoa and tea plantations use this principle. Similarly, root systems of component crops may exploit the nutrients in different layers of soil and hence utilize the resources in a better way with much less competition.

Annidation in time: When component crops of widely varying duration are planted, their peak demand for light and nutrients are likely to occur at different periods, thus reducing competition. In a combination having early and late maturing crops (sorghum + red gram), when early maturing crops are harvested, conditions become favourable for the late maturing crop (red gram) to put forth its full vigour.

Other complementary effects

In an intercropping system involving a legume and a non-legume, part of the N fixed in the root nodule of the legume may become available to the non-legume component. With the presence of rhizosphere microflora and mycorrhiza, one species may lead to mobilization and greater availability of nutrients not only to the species concerned but also to the associated species. Provision of physical support by one species to the intercropped climbing species may improve the yield of the climber. Examples are coconut + pepper and maize + beans. The taller component acts as wind barrier protecting the shorter components from lodging.

Lecture 5. CROPPING SYSTEM MANAGEMENT: AGRONOMIC REQUIREMENT FOR CROPS AND CROPPING SYSTEM - SELECTION OF CROPS AND VARIETIES, TILLAGE AND LAND SHAPING, PLANT POPULATION AND CROP GEOMETRY

1. Selection of Crops and Varieties in cropping system management

1.1 Selection of crops for sequential cropping

Irrigation water availability: If supplemental irrigation facilities are available in rice fallows crops like cotton, groundnut and gingelly can be grown. If it is not available only rice fallow pulse like blackgram can be raised with residual moisture.
Similarly, in garden lands, if adequate irrigation facilities available during summer, a three crop sequence of ragi-cotton-sorghum, accommodating sorghum during summer can be followed. If water is not adequate only double crop sequence of ragi-cotton-fallow is adopted.

Soil type: In lowlands, to increase the cropping intensity, rice fallow cropping is recommended. The type of crop to be included is decided by the soil type also. In old delta area with heavy clay soil, cotton/ pulse is suitable but not groundnut. Whereas, in new delta area where the soil is sandy with light texture, crops like groundnut and gingerly can be grown.

Total returns: Depending upon the price and marketability as well as proximity to the town, the selection of crops will vary. In farms nearer to town, high intensity cropping is possible by including short duration vegetables, greens and fodder crops which are quickly perishable.

Multiple requirements of farm and farmer: Farmer's family / livestock requirements like cereals, millets, pulses, cash crops of longer and shorter duration and also fodder crops. An ideal cropping scheme in a farm must have about 60-70% area under commercial crops 30% food crops and 10% with fodder crops.

Maintaining soil fertility:

- The nature of crops selected in the intensive cropping should help to maintain the soil fertility and not exhausting it completely.
- There should be at least one legume crop in the cropping to maintain the fertility of soil.

Time of sowing of second crop also influence the choice of crops: If the second crop is sown in the standing first crop, the seeds will germinate before the harvest of first crop and may suffer some damage during the first crop harvest. Under such situation the crops which can with stand such damages in seeding stage must be selected. Eg. Rice fallow pulses.

Crops which may serve as alternate hosts: For certain pests and diseases alternate host crops must be avoided as succeeding crops. Eg. Bhendi after cotton

Crops which make the best use of solar radiation: Crops which make the best use of solar radiation must be included to the extent possible. Eg. C_4 plants like maize, sugarcane, etc must be included, which are having rapid canopy development in summer when the solar radiation is high.

Short duration crops: Short duration crops like vegetables, cereals, pulses fodder crops are to be preferred to increase the intensity of cropping.

1.2. Selection of varieties for sequential cropping

For higher productivity- selection of varieties must be done with reference to their yield, sensitiveness to photoperiod and duration – short and medium duration varieties which are photo insensitive to be selected.

a. Duration: Rice fallow season: In pulses, blackgram T9 or CO5. Cotton MUC 9 SVPR 1 (135 days duration) can be selected. If the rice fallow crops are longer duration, it will interfere in the operations of first season rice.
b. Photo sensitiveness: GEB 24 Photosensitive variety and season bound one comes to flowering only during Oct-Nov months. But now all are photo insensitive varieties.
c. Yield: Short and medium duration varieties which are photo insensitive and can be recommended for all seasons and yield higher productivity.

1.3. Selection of crops for intercropping

The factors that have to be considered for selection of crops and varieties for intercropping are as follows

a. Main crop yield does not suffer much
b. Competition between crop species is minimum
c. Complementary effects will be more
d. Pests, diseases or weed incidence is not unduly increased
e. Allelopathic effects
f. Similarly the temporary immobilization of N due to wide C/N ratio immediately after sorghum stalk incorporated is another instance demanding proper residue management (Sorghum effect)

a. Competition for solar radiation in intercropping

In Intercropping situations, competition for solar radiation might arise due to difference in height, leaf area, leaf orientation and growth duration.

i. Height: In intercropping systems, taller components are usually able to intercept more light and shorter components are affected by shading and low light intensities. If the intercrops are shorter they do not pose any competition for light with the main crop.

   Eg., In studies on sorghum based intercropping systems short growing crops like cowpea, soybean and greengram did not compete with sorghum for light and light interception by intercropped sorghum was more or less equal to sole sorghum. But when tall growing sunflower was intercropped in sorghum rows, light interception by sorghum was reduced by 50%.

ii. Leaf area: In a combination of tall and short crops, the amount of solar radiation available to short crops is very much reduced by shading of tall crops. If the shorter components have greater leaf area, leaf area / leaf weight ratio and adaptation to low light intensities, than they will survive better in such intercropping systems and the intercepted light will be of greater use.

iii. Leaf inclination: It refers to leaf orientation based on ideotype of plants. Regarding leaf inclination of component crops for intercropping, an ideal situation would be to have taller components with more erect leaves and the shorter components with more horizontal leaves. So, sufficient light falls on shorter components favouring maximum utilization. Such mixture would intercept and use more light and the competition effect would be minimal.

iv. Growth duration: When component crops have different growth duration, the peak demand for light would occur at different times. In maize + green gram system, peak light demand for maize occurs at about 60 days after sowing, by the time the green gram is ready for harvest. Greengram is able to make use of light available in early stages of maize growth, when shade is less.

Similarly in sorghum + redgram system, redgram grows very slowly in the early stages. At the time of sorghum harvest, redgram reaches its peak light demand period and at that stage shading by sorghum is less / nil.

b. Competition for nutrients in intercropping

Competition for various nutrients between component crops depends on root distribution pattern, growth stages of peak demand period and crop duration

i. Root distribution pattern: When root system of component crops overlap in the same zone, competition for nutrients would occur and the crop with more aggressive growth would suppress the nutrient uptake by the less dominant crop and affecting its growth. So, there must be variation in rooting pattern of component crops.

ii. Peak demand period: Similarly, if the peak nutrient demands periods of the component crops occur at the same time then the competition will be high for the available nutrients. Such competition for nutrients can be minimized by selecting crops of different root distribution pattern. For instance, when a shallow surface rooting millet is intercropped with a deep rooted redgram then the roots of these two crops forage in different soil layers, thus avoiding competition.

iii. Crop duration: Similarly, if the inter crop has either less or more duration than the main crop, then the peak nutrient requirement periods of these two crops would occur at different times and thus competition at any particular time is less. The problem of nutrient competition can further be minimized by selecting crops which require more quantities of different nutrients. Eg. Legumes require phosphorus and millets demand nitrogen. The duration of the crops might decide the nature of intercrops.

c. Complementary effects of intercropping

i. Certain crops require less light intensity and high relative humidity. Altered micro climate is provided when such crops are grown in between tall growing components in an inter cropping system.

   Eg. Turmeric / Ginger / Black pepper in coconut gardens.

ii. Similarly when legumes are intercropped with non-legumes of a longer duration, N-fixed by legumes would benefit the non – legumes

iii. Presence of rhizosphere *microflora* and *mycorrhiza* associated with one of the crops may lead to mobilization and availability of nutrients which may benefit the associated crop also.

iv. Similarly provision of physical support by a tall crop to a climbing type of intercrop is another example of complementary effect.
Eg. Coconut + pepper, sorghum + lablab, maize + climbing beans

v. Tall components may provide protection against wind for the short component crop

d. Allelopathic effects

Some crops may be unsuitable as intercrops because they secrete toxins into the soil which will adversely affect the associated crops. Roots of cucumber, leaves of Eucalyptus globules, decomposing residues of sunflower are known to produce allelo chemicals, affecting the growth of other crops. Such crops must be avoided.

e. Pests, diseases and weeds infestation

There are instances where certain species of crops when grown together result in more in a dense of particular pest / disease / weeds affecting the other crops. Such combinations must be avoided.

Ultimately the final aim in selection of crops for intercropping must be

a. To ensure normal yields of main crop and additional yield from intercrop (or)

b. To produce a higher total yield from both crops than what either of them would have produced as pure crops

1.4. Selection of varieties for intercropping

Even within a combination of two particular crops, selection of varieties of each crop suitable for inter cropping may become necessary. Genotypes suitable for sole cropping may not be suitable for intercropping situations and may be based on the following criteria.

a) differences in duration
b) differences in distribution of leaves on the stem
c) differences in rooting pattern
d) differences in growth habit

Eg. In sorghum + cowpea intercropping system, a sorghum variety of 100-120 days duration mixed with cowpea genotypes of 75-90 days duration and erect compact canopy without tendrils having deep root systems than sorghum would produce better results.

1.5. Selection of crops for multi-tier cropping

Besides the criteria mentioned for intercropping other points to be considered are,

- Differences in canopy height to make use of solar radiation available at different heights from the ground level.
- Crops maturing in different periods so as to provide income at short and regular intervals in a perennial plantation
- Crops of different rooting pattern to avoid overlapping and to facilitate exploitation of larger and deep soil layers
- Crops which need shade and low temperature and increased humidity.

1.6. Selection of crop for border/bund cropping

- Should not require extra care
- Should withstand damage due to passage of human and cattle
- Mature earlier or along with the main crop

- Should not create any border effects due to shade or root effect on the main crop

2. Tillage and land shaping in cropping system management

In sequential cropping, the main aspects to be considered are

a. When cropping intensity is increased i.e. more crops are raised in one year, the time interval between any two crops is very much reduced and this would affect the intensity of tillage and tillage operations are not carried out thoroughly.

b. Preparatory cultivation for second crop(s) is to be carried out and completed very quickly to enable sowing of the succeeding crops in time. Delayed planting of one crop would not only reduce its yield but also delay the sowing of the next crop and as a result the total productivity would also suffer.

In double crop rotation,

Eg. Sorghum – (March –June): 110 days } 260 days

Cotton – (August – January):150 days

Here after pulling out of cotton stalks, field can be ploughed leisurely for sowing sorghum crop and similarly there is one mouth gap after sorghum harvest for preparatory cultivation to the subsequent cotton crop.

For Triple crop rotation,

Ragi (May – August) - 90 days } 340 days

Cotton (August – January) -150 days

Sorghum (Feb – May) – 100 days

Very little time is left for land preparation for ragi and cotton. If land preparation after sorghum is delayed, ragi seedlings would become aged and yield will be reduced. If ragi is planted late, it would delay the cotton sowing or affects its yield.

c. In some instances, to avoid delay in planting desired land shaping of the succeeding crop may not be possible before sowing and may have to be done late.

Eg. Rice-fallow pulse/cotton

Pulses have to be sown before moisture is last after the harvest of rice. Any normal preparatory cultivation like ploughing, forming beds would lead to soil drying and affect the germination and establishment of pulses. In rice fallow cotton thorough preparation of field for cotton including ploughing, forming ridges would invariably delay the sowing of cotton and result in delayed harvest of cotton affecting planting of first crop rice in the next season.

d. Increase in cost of cultivation due to increase in land shaping in the sequential cropping systems.

Management of tillage operations and land shaping can be done by the following means

a. To overcome the shortage of time between crops, use of implements and machinery which will reduce the time required for field preparation and land shaping can be resorted. Eg. Use of tractor drawn plough harrows, cultivators, cage wheel etc.

b. Animal / tractor drawn bed former, furrow opener, seed drills etc.

c. Two to three operations at a time (once over tillage) can be covered with certain implements. Animal drawn or tractor drawn seed drill – opens the soil, places the seeds, places the fertilizer and covers the seeds and fertilizers.

d. To check the increase in cost of operations use of labour saving implements may be followed. Eg. Bund former, Ridge plough, seed drill.

e. Minimal tillage to reduce the number of ploughing to the maximum possible.

f. Zero tillage – sowing crops without any preparatory cultivation

g. Chemical tillage and mulching

h. Off-season tillage

i. Land shaping after crop establishment

j. Relay cropping

k. Semi-permanent land shaping

Measures to reduce main field duration

a. Minimum tillage

It refers to restricting the number of tillage operations to the minimum possible required level to facilitate germination and establishment and also to restrict the tillage operations to the seeding zone only within the field.

For eg. Instead of 3-4 ploughings which is normally given, if reasonable tilth can be obtained within 1-2 ploughings, to that extent preparation can be completed early.

In most of the crops, the seeding zone has been defined as the area around the growing young plant about 20cm deep and 10cm diameter for widely spaced crops. For closely planted crops the seed zone would be 10cm wide along the crop row. In the minimal tillage, only the seed zone is tilled intensively and the inter space is not ploughed or ploughed once. This would reduce the time required for tillage.

Many advantages are attributed to the minimal tillage

a) Cost reduction, b) Time saving, c) Reduced run off and erosion, d) Reduced evaporation,
e) Reduced soil temperature.
However, in heavy poor drained soil, minimal tillage may not be effective.

b. Zero tillage

Soil is not disturbed mechanically and not opened up. For placing the seeds alone the soil is opened. Succeeding crop is sown, without any preparatory cultivation in the stubbles of the previous crop. Advantages are i) cost reduction, ii) time saving, iii) reduced run off and erosion, iv) reduced evaporation, v) reduced soil temperature, vi) soil structure is improved.

For eg. Cotton is sown in ragi stubbles or paddy stubbles. Presence of fibrous roots and stubbles of ragi is believed to reduce surface encrustation and enable easy emergence of cotton seedlings, especially in heavy soils. Fallow cotton in paddy avoids delay due to field preparation and cotton growth can be completed before the next paddy season commences.

However, the zero tillage is not popular in India as in western countries where the labour is costly and not available, climate is temperate and there when organic matter is placed in the soil , decay is very slow an not rapid. There will be severe weed menace which can be controlled by wide range of herbicides. Under Coimbatore condition with three crop rotations, ragi-cotton-sorghum under zero tillage with chemical weed control, *Cynodon dactylon* became a major problem after the second year and was difficult to control. However, the ragi stubbles are soft with less cellulose fibre when subjected to decomposition and mineralization, encrustation of soil is prevented thereby improving the emergence of cotton seedlings.

c. Chemical tillage and mulching

In both minimal and zero tillage, the main problem is weed infestation and regrowth of crop stubbles, in the absence of through preparatory cultivation .This can be tackled by the use of suitable chemicals to control the weed growth and regrowth of stubbles of previous crop, which is termed as chemical tillage.

Eg. Application of paraquat in rice stubbles would reduce the seedlings regrowth from the stubbles and weed growth and dried residues will act as mulch. Similarly, pre emergence herbicide for zero tillage plots. Mulching with crop residues in minimal/zero tillage plots helps to control weed growth.

d. Off season tillage

Tillage during non-cropping season in heavy soils, deep and intensive cultivation with tractor drawn disc plough or mould board plough during off season/dry season (summer ploughing) would help to break the hard pan and control perennial weeds and pests like red hairy caterpillar of groundnut (pupal exposure). Minimal tillage during the cropping season would be enough and timely seed be preparation is possible during cropping period favouring timely sowing of crops.

e. Land shaping after crop establishment

This is to overcome narrow time interval and not to miss the correct season of sowing. In some crops sown with minimal or no tillage, suitable land shaping can be done after the crop establishment.

Eg. Cotton sown in ragi stubbles, ridges and earthing up operations are carried out at the time of first top dressing of nitrogen at 30-35 DAS. Similarly, forming ridges and furrows for rainfed cotton at 30-40 days after sowing to avoid delay in sowing season.

f. Relay cropping

There is a very quick succession of crops to avoid delay between crops, sowing the succeeding crops in the standing previous crop may be practiced without any land preparation. It saves time and reduces the cost for land preparation.

Eg. Rice fallow blackgram, 10-15 days before the harvest of paddy, pulse is sown. Relay sowing of horse gram in standing crop of ragi under rainfed conditions of Salem and Dharmapuri and Pudukottai districts of Tamil Nadu.

Salkepai: dropping the ragi seedlings behind the country plough in furrows during South West Monsoon periods and horsegram sowing in North Western Zone of Tamil Nadu.

g. Semi permanent land shaping

Land is shaped not temporarily but for a period of few years. In drylands, where double cropping is practiced i)to ensure timely sowing of second crop and ii)to overcome the problem of heavy rainfall, making it difficult for land preparation during the interval between two crops, seed beds may be formed on a permanent basis.

Eg. Broad Bed Furrow system (BBF) is a classic example of this practice. These are formed during off season and can be maintained for 3 to 4 seasons with light harrowing of seed beds only at intervals to kill the weeds, to close the cracks on the surface for sowing the succeeding crops.BBF system is a semi permanent structure. 120cm bed width, 30cm deep furrow, suitable for vertisols or black cotton soils, where double cropping is possible under rainfed conditions.

The land is thrown in to beds and furrows with a mild gradient of slope (0.4 to 0.8%) with the receipt of heavy rains, there will be water stagnation in black clay soils as it has heavy clay content (> 52 per cent). So, the soil cannot be brought for early sowing of both first and second season crops, which may be delayed leading to crop failure. So, if the land is brought into beds and furrows with gentle gradient, the excess water is trained through many small channels, thereby preventing soil erosion. In addition soil will be friable which is required for early sowing.

In our state it is having limited applicability because of lesser black soil areas with heavy rains. But, highly suitable for MP and Maharashtra where sorghum-safflower/ sunflower/Bengalgram/mustard is being practiced.

Other measures to reduce main field duration

- Short duration varieties
- Raising nursery and transplanting
- Hastening the maturity of crops
- Paraquat spray in cotton-boll bursting
- NaCl in rice-maturity is rapid
- Ripeners in sugarcane
- Harvesting at physiological maturity

i.e. Seeds or grains will be having maximum vigour and viability but has more moisture than when the seeds are collected during normal harvest time. Similarly, in millets if harvested earlier, the fodder will be greenish.

- Relay sowing will reduce the main field duration of both crops in the sequence
- Ratooning
- Avoiding delay in maturity due to excessive vegetative growth.

Crops	Plant/sown crop duration (days)	Ratoon crop duration (days)
Sorghum	105-110	75-80
Paddy	110-115	80-95
Surgarcane	360	300

3. Plant population and crop geometry in cropping system management

The yield advantage in an intensive cropping system depends to a larger extent on the establishment of a good crop stand in which the component crops enjoy a favourable environment to perform well and increase the benefits of crop associations. Besides routine aspects like good seeds, correct and ideal seed bed preparation, optimum moisture in soil and removal of weeds, the establishment of a good crop stand also depends on optimum population of component crops, proper crop geometry, suitable method and time of sowing. The significance of these management aspects are relatively more important in intercropping than in sequential cropping since in the intercropping competition occurs both in space and time dimensions, affecting stand establishment. Therefore, there should be optimum population of both the component crops.

a. The planting pattern should be modified to avoid competition

b. The time and method of sowing also should be altered to minimize competition.

i) Optimum population of component crops

In the intercropping when two or more crops are raised together, the total population of plants per unit area is normally more than that of the sole crops on base crop. The proportional population of each component must be carefully fixed in order to avoid competition leading to poor growth of either or both the crops and total yield advantage of intercropping system would be reduced.

Depending upon the objective and competition the population of the component crops will vary.

a. When a near full yield of the base crop is defined, the main crop population must be equal to that when it is raised as sole crop and intercrop population has to be lesser than under its pure crop. It may vary 30-50% of pure crop population. This is true especially when intercropping is also equally competitive.

b. In intercropping, if one of the crops is more dominant and competitive, the other crop is likely to suffer and its individual plant performance would be lower than when it is raised as pure crops. In order to maintain yield advantages and to make up the loss in individual plant performance, the intercrop population may be increased even upto 100 % of sole crop, provided the main crop is not affected.

c. In other situations, where a particular combination of crops is likely to result in only a total yield advantage or increase, but the performances of either of the crops is likely to be less than under sole crops, the proportionate population of component crops must be fixed so as to get the highest yield advantage.

ii) Crop geometry in intercropping system

After fixing the plant population, if sown as such then there will be a competition. Even in wide spaced crops, when intercrops are raised, suitable alternations in row arrangement should be made.

Distribution of plants over the ground area is called as crop geometry. It also refers to the shape of the land area available to the individual plants. The shape is altered by changing the row arrangement.

Sowing crops in the normally recommended uniform row spacing of pure crops would afford little or no opportunity for accommodating a companion cropping. On the other hand a modification of the planting pattern of the base crop would make intercropping feasible and often remunerative. This is made possible by keeping the plant population density per unit area constant, altering the orientation of rows within certain limits, which does not result in any deviation in yield of the crops. Possible changes in crop geometry for the base crop in an intercropping system from that of pure crop would be

i. wider inter row spacing and reduced intra row spacing

eg. 60 x 30 cm - redgram
90 x 20 cm

ii. Paired rows of main crop or base crop
eg. Sorghum 45 x 15 cm (or) 60/30 x 15 cm

iii. Uniform row planting with a replacement of main crop rows by intercrop rows
eg. Sorghum + Black gram at 2:1 ratio

Examples

i. In sorghum, 45 cm inter row spacing is too close for raising an intercrop. If the row spacing is increased to 60 cm and plant spacing is reduced to 10 cm from 15 cm, the sorghum population would not be reduced much, and the inter space of 60 cm is sufficient for raising one row of inter crop.

ii. Paired row planting of main crop provides adequate inter space for sowing intercrops

45 x 15 cm	60/30 x 15 cm
60 x 30 cm	90/30 x 30 cm

iii. In many intercropping system to accommodate intercrop one or more rows of main crops are replaced by intercrops

eg. Groundnut + Redgram - 6:1
Sorghum + Redgram - 8:1

Lecture 6. CROPPING SYSTEM MANAGEMENT: AGRONOMIC REQUIREMENT FOR CROPS AND CROPPING SYSTEM - WATER MANAGEMENT, SOIL FERTILITY MANAGEMENT AND PLANT PROTECTION

WATER REQUIREMENT

Different losses like percolation, seepage, runoff etc., occur during transport and application of irrigation water. Water is needed for special operations such as land preparation, transplantation, leaching etc. Water requirement of a crop (WR), therefore, includes evapotranspiration, application losses and water needed for special purpose.

WR = ET + Application losses + Water for special purposes

Water requirement is a demand; whereas, the supply consists of contribution from irrigation water, effective rainfall (ER) and soil profile contribution including that from shallow water table (S).

WR = IR + ER (Effective rainfall) + S (Soil profile contribution)

Irrigation requirement

Irrigation requirement is the total amount of water applied to a field to supplement rainfall and soil profile contribution to meet the water needs of crops for optimum growth.

Irrigation requirement (IR) = WR – (ER +S)

The net irrigation requirement is the amount of irrigation water just required to bring the soil moisture content in the root zone depth of the crops to field capacity. Thus, the net irrigation requirement is the difference between field capacity and soil moisture content in the root zone before irrigation. Gross irrigation requirement is the total of net irrigation requirement and other losses such as conveyance, distribution and application or total depth of water required for entire crop period.

FACTORS AFFECTING WATER REQUIREMENT

The water requirement of any crop is dependent upon

(1) Crop factors: Variety, growth stage, duration, plant population and growing season
(2) Soil factors: Texture, structure, depth and topography
(3) Climate factors: Temperature, relative humidity and wind velocity
(4) Crop management practices: Tillage, fertilization and weeding etc.

Water requirement of crops vary from area to area and even from a field to a field on a farm depending on the above mentioned factors. It is, therefore, not appropriate to make general statements of water requirement of a crop or specify the number of irrigation or irrigation interval for a crop. Instead, indicating the development stages of crop when it is essential to give irrigations and avoid moisture stress is more meaningful. The need for irrigation at other stages of crop growth are best decided based on the amount of moisture available in the soil and needs of the crop.

Crop factors

Varieties of the same crop differ in duration, rooting pattern and canopy structure. The variety, with longer duration obviously requires more water for completion of the life cycle. During the growth of crop, consumptive use is maximum during flowering and grain filling in cereals compared to that in seedling stage. Crops differ in producing leaf area and covering the ground. Higher the leaf area index, more is the evapotranspiration. Evapotranspiration also differs with height of the crop. Tall crops intercept more solar radiation and have more evapotranspiration than short crops.

Soil factors

Evapotranspiration from soils differ due to their difference in hydraulic conductivity, reflectivity and thermal conductivity. At higher moisture regimes, coarse textured soils have higher hydraulic conductivity than fine textured soils. With the result, evaporation is faster in coarse textured soils under intermittent wetting and drying. Evaporation mostly occurs from the top 5 cm of soil and soil structure up to 15 cm depth influences evaporation through its influence on water supply to evaporation site. Higher percentage of aggregate of more than 1.0 mm diameter, reduce the upward movement of water and hence, evaporation. Formation of ridges and furrows reduces evaporation due to the presence of large sized aggregates. Colour of the soil also has considerable influence on evaporation from the soil surface. Dark coloured soils absorb more of solar radiation and thus, increase evaporation.

Climate factors

It is well known that evapotranspiration is strongly influenced by solar radiation, temperature, relative humidity and wind velocity. In addition, advective energy also influences evaporation. Hot and dry area surrounding the irrigation are increases evaporation. Advection is a serious problem in arid and semi-arid regions.

Crop management practices

All the management practices that provide favourable environment to the crop increase the leaf area and thus, increase evapotranspiration. Tillage practices influence rooting characteristics and thus influence evapotranspiration. Frequent irrigation results in higher proportion of evaporation. Weeding reduces competition for moisture and increases irrigation interval. Similarly, mulching reduces evapotranspiration considerably.

Water Management in Cropping System

Water management has to be studied with reference to

1. Total water requirement
2. Scheduling of irrigation

1. Total water requirement

Knowledge of anticipated total water requirement of different types of intensive cropping systems would help us to select or choose the one that would suit to water availability situation. In an irrigated condition, total water requirement would include the water lost through ET by various component crops, water needed for land preparation, water lost during conveyance. In rainfed land, total water requirement is the water lost through ET by component crops. Let us examine the total water requirement in some intensive cropping on water management.

a. Intercropping

i. Rainfed

Pure pearl millet	159mm
Pure groundnut	196mm
Pearl millet + groundnut	228mm
Increase due to intercropping	32-69mm

ii. Irrigated

System	SW monsoon	Summer
Groundnut pure	562 mm	698 mm
Groundnut + Greengram	612 mm	745 mm
Increase due to intercropping	**50 mm**	**47 mm**
Sorghum	419 mm	424 mm
Sorghum + cowpea	490 mm	523 mm
Increase due to intercropping	**74 mm**	**99mm**

It is evident that introduction of a component crop between the rows of main cop, naturally increases the total population and consequently increases the total water requirement. But this increase is very minimal. Comparing the minimal increase in total water requirement and the high total yield, the water use efficiency of intercropping is more i.e. the production per hectare cm of water is high.

b. Sequential cropping

When the number of crop raised in a field in one year increases the total water requirement of the cropping system also increases.

Eg. Wetlands	Rice-Rice-Rice	=	3500 mm
	Rice-Rice-Pulses	=	2300 mm
	Rice-Rice-Ragi	=	2750 mm
Garden lands	Cotton – Sunflower – Finger millet	=	1925 mm
	Cotton – Sorghum - Finger millet	=	1975 mm
	Cotton – Maize – Ragi	=	1985 mm

Such information in total water requirement of different cropping system would be useful for choosing the suitable crop sequence based on water availability.

2. Scheduling irrigation

Scientific irrigation scheduling is a technique providing knowledge on correct time (When to irrigate) and optimum quantity (How much to irrigate) of water application at each irrigation to optimize crop yields with maximum water use efficiency and at the same time ensuring minimum damage to the soil properties.

Intercropping

i. Intercropping system, the total water requirement varies and critical stages of water requirement of component crops may not coincide. If one crop is irrigated based on its requirement, then the other crop may suffer due to excess or stress.

Eg. Cotton + blackgram, cotton needs dry spell in the first 20-25 days but this may affect blackgram.

ii. More number of irrigations may be necessary in intercropping than in pure crop, because of increased total water requirement.

iii. When the intercrop is sensitive to excess water it may be raised in bed furrow system.

Eg. Surgarcane + soybean

Soil Fertility Management in Cropping System

Determining fertilizer schedule for sole crops itself is a complex problem because

- many factors affecting availability,
- fixation and loss of applied nutrients and
- the difficulty in estimating the soil contribution.

The problem becomes more complex in intensive cropping with the additional factors

- residual effect of nutrients applied to the previous crop,
- possible effect of legumes in the system,
- complementary and competitive interference from the component crops and
- influence of crop residues left in the soil.

Hence, soil management is different for multiple cropping from that for single cropping.

It is well known that soils tend to decline in productivity when they are continuously cropped without adopting satisfactory restorative practices.

Designing nutrient management practices for cropping systems

Three interrelated concepts in designing fertilization practices for multiple cropping systems are

- Selection of species combinations,
- fertility response of a particular species' in multiple cropping relative to monoculture and
- Objectives of the multiple cropping systems.

The most common approach in developing the fertilizer schedule for an intensive CS

- Nutrient Requirement of Component Crops
- Pattern of Nutrient Uptake

- Response to Nutrient Application
- Legume Effect
- Soil contribution
- Rates of Fertilizer Application

Nutrient Requirement of Component Crops

Sugarcane based sequential cropping system

Conventional sugarcane system (one plant + one ratoon in 2 years) which removed 213, 132 and 571 kg N, P_2O_5 and K_2O/ha respectively. The most productive and profitable cropping systems viz., short duration sugarcane / ratoon / finger millet / cotton removed the highest amount of nutrients (357kg N, 214kg P_2O_5 and 807kg K_2O per ha).

One tonne of sugarcane removed 1.05kg N, 0.65kg P_2O_5 and 2.84kg K_2O from the soil

Nutrient competition can be minimized in intercropping systems by

- selecting species with different rooting patterns
- different nutrient requirement
- different times of peak demand for nutrients
- plant spacing.

Pattern of Nutrient Uptake

In cereal-legume intercropping, the legume component is capable of fixing atmospheric N under favourable conditions and this is believed to reduce competition for N with the cereal and intercrop legume compete for available soil N. In a maize+ cowpea intercropping system, the peak period of N requirement for cowpea occurs at 45 days and for maize 55 -60 days. Phosphorus is major nutrient that determines the production potential of most grain legumes usually intercropped with cereals.

Legumes are poorer competitors for P when intercropped with grasses or cereals, this being attributed to differences in root morphology. In a maize and cowpea intercropping system, in the absence of applied P, maize was more competitive than cowpea in the initial stages. However, at high rates of applied P, P uptake of maize was reduced by 30 per cent, indicating competition for P from cowpea.

Response to Nutrient Application

- All crops included in a cropping system are not equally responsive to application of all the major nutrients.

- Based on the response data of individual crops, they can be classified as non-responsive, moderately responsive or highly responsive to specific plant nutrients.
- It would be appropriate to apply fertilizer to those crops which respond to it and little or none to the none-responding crops.

Little information is available on fertility response equations developed specifically for multiple cropping situations. However, regression response equations were developed for sorghum, maize and sugarcane based intercropping systems. Such regression equations could be extended to prediction and optimization of total energy production, protein production, economic yield or whatever the multiple cropping objective may be. However, this approach is empirical and appropriate for specific areas and data sets

Fertility management in a cropping system becomes sustainable if it would make the least demand on soil. In this context the nutrient balance sheet approach is used.

Legume Effect

N fixed by the intercrop of legume may be available to the associated cereal in the current growing season or as a residual N for the benefit of a succeeding cereal crop. Both forms of N transfer are considered to be important and could improve the N economy of various legume-based intercropping systems Hence both current and residual N benefits should be evaluated in intercrop systems in which legumes are a component.

Soil Contribution

- Once the nutrient requirement of a cropping system is known, the next step is to find out how much the soil can contribute to meet the requirement before deciding on the quantum of fertilizer application. The most common method of estimating soil contribution is routine soil analysis.

Rates of Fertilizer Application

After ascertaining the soil contribution, the amounts of nutrients to be applied to the cropping system through fertilizers can be arrived at. It is essential to calculate the nutrient balances to assess the amounts of fertilizers needed to attain the desired level of production and to ensure that the soil fertility is maintained and preferably improved.

Plant Protection Measures in cropping systems management

Intensive cropping systems like intercropping and sequential cropping may increase / decrease the incidence of certain pest and diseases.

- Increase in vegetative cover
- Alteration in micro-climate

  Eg. Sorghum + pulses reduce the early shoot borer incidence

- Leaf miner in groundnut reduced when intercropped with cowpea.
- Castor as trap crop in cotton field.
- Presence of physical barrier affecting the movement of insects.
  Eg. Sorghum + sesame, less damage of web worm to sesame

The pest and disease management strategy include

- Choice of resistant varieties
- Careful combination of crops in intercrop
- Careful combination of crops in sequential crop
- Destruction of crop residues
- Cultural operation for pest and disease control
- Optimum time of sowing
- Judicious use of selective pesticide

Lecture 7. INDICES FOR EVALUATION OF CROPPING SYSTEM - LAND USE, YIELD ADVANTAGE AND ECONOMICS

- Evaluation and productivity of multiple CS or of component crops should be done on quantitative terms
- It is relatively easy to compare the productivity of crops and agricultural systems that produce similar produces and use similar resources.
- A number of efficiencies in resource use becomes operative when two or more crops are present in the same field during the same year and these can be most complex when crops are grown simultaneously
- Information about these biological efficiencies can lead to management options that differ from those in monoculture
- Several indices have been proposed to compare the efficiencies of multiple cropping systems in terms of :
    - a. Land use systems
    - b. Biological potentials (yield advantage)
    - c. Economic viability

a. Indices based on land use systems

1. Multiple Cropping Index (MCI) (Dalrymple, 1971)

2. Cropping intensity / Intensity of cropping (CI)

3. Rotational Intensity (RI)

4. Cropping Intensity Index (CII) (Menegay et. al. 1978)

5. Specific Crop Intensity Index (SCII) (Menegay et. al. 1978)

6. Relative Cropping Intensity Index (RCII)

7. Cultivated Land Utilization Index (CLUI) (Chuang 1973)

1. Multiple Cropping Index (MCI): Dalrymple (1971)

It measures the sum of areas planted and harvested to different crops in a single year divided by total cultivated area times 100.

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

Where,
n = total no. of crops
ai = area occupied by i^{th} crop
A = total land area

Example: Farm Size : 2.5 ha

F. No.

1.	1.00	Rice - Rice - Cotton
2.	0.75	Sugarcane
3.	0.75	Fallow - Rice - Cotton

$$\text{Total area} = \frac{5.25}{2.5} \times 100 = 210\%$$

This is highly useful only for multiple cropping

2. Cropping intensity / Intensity of cropping (CI)

$$CI = \frac{\text{Total cropped area (Gross cropped area)}}{\text{Net cultivated area}} \times 100$$

$$CI = \frac{\text{Area under kharif + rabi + summer crops}}{\text{Area under actual cultivation}} \times 100$$

3. Rotational Intensity (RI)

$$RI = \frac{\text{No. of crops grown in a field}}{\text{Years of rotation}} \times 100$$

Example:

1. Maize – potato – onion: 1 year

$$RI = \frac{3}{1} \times 100 = 300\%$$

2. Maize – sugarcane – onion: 2 years

$$RI = \frac{3}{2} \times 100 = 150\%$$

4. Cropping Intensity Index (CII): (Menegay et. al. (1978)

It assesses a farmer’s actual land use in area and time relationships for each crop or group of crops compared to the total available land area and time, including land temporarily available for production. Efficient cropping zone is judged by CII and LER

$$CII = \frac{\sum_{i=1}^{n} a_i . t_i}{\quad}$$

$$\text{AoT} + \sum_{j=1}^{m} \text{Aj.Tj}$$

n	:	No. of crops grown by a farmer during the time period T
ai	:	Area occupied by the i^{th} crop
ti	:	Duration of the i^{th} crop (in months)
Ao	:	Farmers net area available for cultivation during the entire time period T
T	:	Time period under study
m	:	Total no. of fields temporarily available for cropping during the time period Tj
Aj	:	Land area of j^{th} field
Tj	:	Period Aj available for cultivation

Inference: Nearer to one is more advantageous

5. Specific Crop Intensity Index (SCII): (Menegay et. al. 1978)

It is the derivative of CII and determines the amount of area-time denoted to each crop or group of crops compared to the total time available

$$\text{SCII} = \frac{\sum_{i=1}^{Nk} \text{ak. tk}}{\text{AoT} + \sum_{j=1}^{m} \text{Aj.Tj}}$$

N_k = Total no. of crops during T
a_k = area occupied by K^{th} crop
t_k = duration of K^{th} crop

6. Relative Cropping Intensity Index (RCII)

It is the modification of CII and determines the amount of area-time allotted to one crop or group of crops relative to the area-time actually used in the production of all the crops in a farm.

$$\text{RCII} = \frac{\sum_{k=1}^{Nk} \text{ak. tk}}{\sum_{i=1}^{Nc} \text{ai.ti}}$$

It is used for classifying farmers viz., when relative vegetable Intensity Index is more than 50% then farmers will be called vegetable grower.

7. Cultivated Land Utilization Index (CLUI): Chuang (1973)

It is calculated by summing the products of land area planted to each crop, multiplied by the actual duration of that crop and divided by the total cultivated land area with times (365 days).

$$CLUI = \frac{\sum_{i=1}^{n} ai.\ di}{A \times 365}$$

n	:	Total no. of crops
ai	:	Area occupied by the i^{th} crop planted and harvested within one year
di	:	Days that i^{th} crop occupied area(ai)
A	:	Net area for 365 days

Lecture 8. INDICES FOR EVALUATION OF CROPPING SYSTEM - YIELD ADVANTAGE AND ECONOMICS

I. Indices Based on Biological Potential (yield advantages)

Indices based on Biological potential are categorized into production efficiency index and interference indices.

a. Production Efficiency Index

1. Crop Equivalent Yield

Crop Equivalent yield: The equivalent yield should preferably be calculated in terms of kharif crop (say paddy in rice based cropping system) using the following formula.

$$CEY = \frac{Yi \times Pi}{Pb}$$

CEY = Crop equivalent yield

Yi = Yield of individual crop

Pi = Price of individual crop

Pb = Price of base crops

Example: Yield and cotton equivalent yield of crops in different sequential cropping systems

Crop sequence	Grain yield (kg/ha)				Cotton equivalent yield (kg/ha)			
	K	R	S	Total	K	R	S	Total
Cotton -Finger millet-Sorghum	1903	2833	2460	7196	1903	708	738	3349
Beetroot - Green gram - Maize	9937	1035	5626	16598	2484	1035	1969	5488
Cowpea - Gingelly - Maize	962	762	5246	6970	481	1524	1836	3841
Cotton – S.culeate - Sunflower	1656	12054	1633	15343	1656	301	1388	3345

Produce market Prices (Rs./kg)

Cotton : Rs. 20 Finger millet : Rs. 5 Sorghum : Rs. 6 Beetroot : Rs. 5

Green gram :Rs. 20 Maize : Rs. 7 Cowpea : Rs. 10 Gingelly : Rs.40

S.aculeate : Rs. 0.50 Sunflower : Rs. 17

One other form of single measurement comparison which is exactly equivalent to the financial value index, is the crop equivalent.

In calculating a crop equivalent, yield of one crop is converted into yield equivalent of the other crop by using the ratio of prices of the two crops.

2. **Land Equivalent Ratio (LER):**

LER reviewed by Willey (1979). LER is the relative land areas under sole crop required to produce the same yield as obtained under a mixed or inter cropping system at the same level of management. It is the ratio of land required by pure crop to produce the same yield as that of intercrop.

$$LER = \frac{Ya}{Sa} + \frac{Yb}{Sb}$$

Ya & Yb : Yield of individual crops 'a' and 'b' respectively in mixture.
Sa & Sb : Yields of individual crops 'a' and 'b' respectively in pure stand.

Inference : When LER > 1, intercropping is beneficial

Thus, it gives a better picture of the competitive abilities of the component crops. It also gives actual yield advantage of intercropping.

In another words LER is the unit to measure the production efficiency of different intercropping system by converting the production in terms of land acreage. LER gives an accurate assessment of the biological efficiency of intercropping.

3. Relative Yield Total

The most important index of biological advantage is the relative yield total (RYT) introduced by De Wit and Van Den Bergh (1965).

The mixture yield of a component crop expressed as a portion of its yield as a sole crop from the same replacement series is the relative yield of the crop and the sum of the relative yields of component crops is called relative yield total (RYT). Both the expressions (RYT and LER) are similar.

Example

Yield of groundnut and pigeon pea as sole crops were 1000 and 500 kg ha^{-1}. Corresponding yield in intercropping was 700 and 400 kg $ha^{-1.}$ Price of pigeon pea is Rs.12 kg^{-1} and that of groundnut Rs.12 kg^{-1} . Calculate LER.

Solution

$$LER = \frac{700}{1000} + \frac{400}{500}$$

$$= 1.5$$

There are two different objectives for which such indices have been proposed.

The first is the assessment of the benefit or overall advantage of intercropping and the second is the assessment of the relative performance of the two crops, the concept of dominance or competitiveness.

It is important not to confuse these two objectives, which should be quite separate conceptually.

The RYT or LER is the main index of advantage currently used.

4. Area time equivalent ratio (ATER)

It takes into account the duration of crops and permits an evaluation of crops on yield per day basis. It is a modification of LER.

$$\text{ATER} = \frac{(LA \times DA) + (LB \times DB)}{T}$$

Where, LA and LB are relative yield or partial LER of component crops A and B. DA and DB are duration of crops A and B and T are the total duration of the intercropping system.

5. Staple land equivalent ratio (SLER)

In situations, where the primary objective is to produce fixed yield of one component (staple) and some yield of other crop, the concept of SLER is proposed.

$$\text{SLER} = \frac{MDA}{SA} + P\left\{\frac{MB}{SB}\right\}$$

Where, MDA is derived yield of A in mixture yield and P the proportion of land devoted for intercropping. MB is yield of intercrop in mixture and the yield of crops grown as sole crop are SA and SB.

b. Interference Efficiency

1. Relative Crowding Coefficient (RCC): Proposed by De Wit (1960)

It is used in replacement series of intercropping.

It indicates whether a species or a crop, when grown in mixed population, has produced more or less yield than expected in pure stand.

In 50 : 50 mixture

$$\text{Kab (RCC)} = \frac{\textit{Mixture yield of a}}{\textit{Pure stand yield of a} - \textit{Mixture yield of a}}$$

$$\text{Kab} = \frac{Yab}{(Yaa - Yab)}$$

For all mixture

$$Kab = \frac{Yab \times Zba}{(Yaa-Yab)\ Zab}$$

Yab = mixture yield of crop ‘a’ grown with ‘b’
Yba = mixture yield of crop ‘b’ grown with ‘a’
Yaa = Yield in pure stand of crop ‘a’
Ybb = Yield in pure stand of crop ‘b’
Zab = proportion of sown species ‘a’ in mixture with ‘b’
Zba = proportion of sown species ‘b’ in mixture with ‘a’

$K > 1$ Means yield advantage (more yield than expected)
$K = 1$ No difference
$K < 1$ Yield disadvantage (less yield than expected)

RCC and LER give the yield advantage but only LER given the magnitude of advantage. Therefore LER is preferred to assess the competition effects and yield advantage in intercropping situations.

2. Aggressivity

Proposed by Mc Gilhrist (1965). It is the mixture of how much the relative yield increase in component ‘a’ is greater than that for component ‘b’.

$$Aab = \frac{\text{Mixture yield of a} - \text{Mixture yield of b}}{\text{Expected yield of a} - \text{Expected yield of b}}$$

$$\text{Aggressivity} = \frac{Yab}{Yaa \times Zab} - \frac{Yba}{Ybb \times Zba}$$

Aab = 0 means component crops are equally competitive
Aab = negative means dominated
Aab = bigger value either positive or negative means bigger difference in competitive abilities.

3. Competition Index (CI) : Donald (1963).

It is a measure to find out the yield of various crops when grown together as well as separately. It indicates the yield per plant of different crops in mixture and their respective pure stand on an unit area basis.

If the yield of any crop, grown together is less than its respective yield in pure stand then it is harmful association but on increased yield means positive benefit.

$$CI = \frac{(Yaa-Yab)\ x\ (Ybb-Yba)}{Yaa\ x\ Yab}$$

4. Competition Ratio (CR)

Proposed by Willey and Rao (1980)

$$Cra = \frac{Yab}{Yaa \times Zab} + \frac{Yba}{Ybb \times Zba}$$

It is simply the ratio of individual LERs of the two component crops, but correcting for the proportion in which they were initially sown.

5. Competition Coefficient (CC)

Ratio of the Relative crowding coefficient (RCC) of any given species in the mixture.

$$CC = \frac{RCC\ of\ given\ spp}{Total\ RCC\ of\ all\ crops\ in\ mixture}$$

It is used to find out the relative crowding from which maximum yield can be obtained without any adverse effect on any of the species.

II. Evaluation of CS - Indices Based on Economic Viability

1. Gross return

The total monetary returns of the economic produce such as grain, tuber, bulb, fruit, etc and by 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 expresses in terms of unit area, usually one hectare.

2. Net return or net profit:

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 calculation only the variable costs are considered

3. Returns / rupee invested

Also called as benefit cost ratio or input output ratio.

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

4. Per day return

Also called as income per day and can be obtained by dividing the net returns by number of cropping period (days)

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

5. Diversity Index (DI): Strout and Wang and Yu (1975)

It measures the multiplicity of crops or farm products which are planted in a year by computing the reciprocal of sum of squares of the share of gross revenue received from each individual farm enterprise in a single year.

$$\text{Diversity Index} = \frac{1}{\text{Total square of different crops / components share}}$$

Example: In the following farms, which farm is mostly specialized.

Crops	Income (Rs.) From Different Farms		
	A	B	C
Sugarcane	30,000	-	10,000
Cotton	10,000	20,000	20,000
Wheat	40,000	29,000	10,000
Jowar	20,000	10,000	40,000
Potato	-	50,000	-
Total	100,000	100,000	80,000

Solution

Crops	Shares of individual crops in different Farmer Participatory research on Integrated Farming System in Low External Input Sustainable Environment					
	Farm A		Farm B		Farm C	
	Share	Square of its share	Share	Square of its share	Share	Square of its share
Sugarcane	0.3	0.09	-	-	0.125	0.0156
Cotton	0.1	0.01	0.2	0.04	0.25	0.625
Wheat	0.4	0.16	0.2	0.04	0.125	0.0156
Jowar	0.2	0.04	0.1	0.01	0.50	0.2500
Potato	-	-	0.5	0.25	-	-
Total	1.0	0.30	1.00	0.34	1.00	0.3437

$$\text{Farm A} = \frac{1.00}{0.30} = 3.33$$

$$\text{Farm B} = \frac{1.00}{0.34} = 2.94$$

$$\text{Farm C} = \frac{1.00}{0.3437} = 2.91$$

Inference: Farm A is more diversified and Farm C is more specialized. Lower the diversity Index, higher the specialization

Harvest Diversity Index = $\frac{1}{\sum_{i=1}^{n} yi \sum_{i=1}^{n} yi}$

Where, yi = gross value of the i th crop planted and harvested within a year.

Lecture 9. Farming system: definition, principles and concepts and factors influencing choice and size of enterprises

Why sustainable farming system

- Soil degradation
- Waste and overuse of water
- Pollution of the environment
- Dependence of external inputs
- Loss of genetic diversity
- Loss of local control over agricultural production
- Global inequality

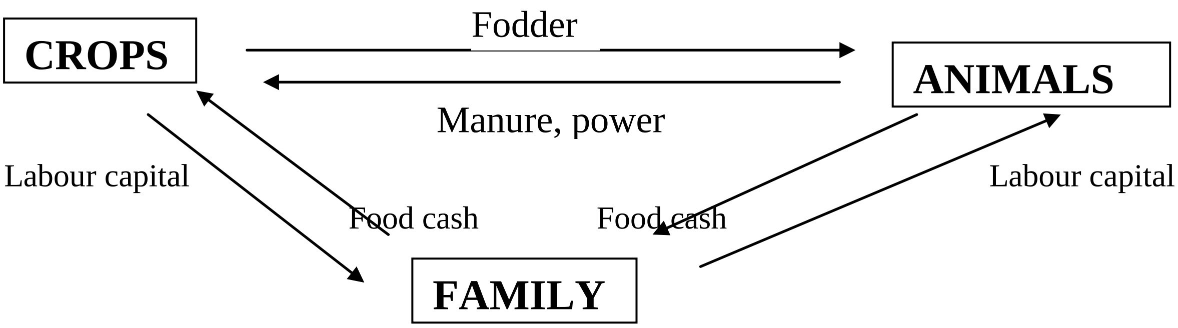
System

A System is an assembly of objects or things, which are interrelated and interdependent on each other for proper functioning to achieve a common objective Eg. Human body consists of digestive system, circulatory system and nervous system

Farming System

Farming system is the entire complex of development, management and allocation of resources as well as decisions and activities, within an operational farm unit, or combinations of units, results in Agricultural production and processing and marketing of the products (Krantz, 1975).

Farming system is a decision making unit comprising the farm household, cropping and livestock systems that transform land, capital (external inputs) and labour (including genetic resources and knowledge) into useful products that can be consumed or sold. (Fresco and Westphal, 1988)



Population in India

2000 : 100 crores
2030 : 137 crores
2050 : 166 crores

Food need

1990 : 176 metric tonnes
2000 : 210 metric tonnes
2030 : 289 metric tonnes
2050 : 347 metric tonnes

Land area

1990 : 143.8 Million hectare
2000 : 141.3 Million hectare
2050: 131.3 Million hectare

Farming System?

- Population increase
- Shrinking land area
- Over use of chemicals
- Soil health deterioration
- Waste and over use of water

Scope

- The rising cost of energy
- The low profit margins of conventional practices
- Development of new practices that are seen as viable options
- Increasing environmental awareness among consumers, producers and regulators
- New and stronger markets for alternatively grown and processed farm products
- 44 out of 453 dist contributing half of the total food grain
- No further scope for horizontal expansion of land for cultivation

Three Working Hypotheses of Farming Systems

1. There is always a reason why farming is carried out in one way rather than another. The reason is often, but not always, an economic one
2. Change in the environment of the system generally produces discrepancies between the actual farming systems employed and the optimum solution given for the farmers possibilities and preferences
3. Farmers tend to adopt their farming to the changing circumstances, provided the change is satisfying in terms of additional benefits

Objectives

- Increasing the total farm income as a whole
- Improving the standard of living of the farmer
- Effective recycling of farm products and by-products
- Reduce the external input usage on the farm (LEISA)
- Sustaining the productivity levels and soil health

- Increasing the employment opportunities
- Regular cash flow through out the year

Environment

Farm as a system functions within environment consisting of natural, socio economical and political features

Resources

Various physical and material requirements generated inside or outside the system

Constraints

Problems caused by the limitation and availability of natural and artificial resources

Components

Constituent activities like crop production, dairy, poultry etc.,

Interaction

Competitive interactions and complementary interactions

Definition

A farming system is a collection of distinct functional units such as crop, livestock, processing, investments and marketing activities which interact because of the joint use of inputs they receive from the environment which have the common objective of satisfying the farmers' (decision makers) aims. The definition of the borders of the options depends on circumstances; often it includes not only the farm (economic enterprise) but also the household (farm–household system)" **Ruthenberg (1971)**

A farming system is not simply a collection of crops and animals to which one can apply his input or expect immediate result. Rather, it is a complicated interwoven mesh of soils, plants, animals, implements, workers, other inputs and environmental influences with the strands without link help and manipulated by a person called farmer, who given his preferences and aspirations, attempts to produce output from the input with the technology available to him. It is the farmer's unique understanding of his immediate environment, both national and socio economic that results in a "Farming system". Thus, Farming system (farm system or whole farm system) is the production and consumption activities used by a person called a farmer to derive benefits from land and other inputs through crop growth and the use of technologies available to him under specific environmental conditions. **Zandstra et al. (1981)**

Farming is the process of harnessing solar energy in the form of economic plant and animal products, and 'System' implies a set of inter related practices/processes organized into a functional entity, i.e. an arrangement of components or parts that interact according to some process and transforms inputs into outputs. Faming system is a decision making units comprising farm household, cropping and livestock systems that transform land, capital and labour into products for consumption and sale.

Farming system is a set of agro-economic activities that are inter-related and interact among themselves in particular agrarian settings. Farming system is the mix of farm enterprises to which farm families allocate its resources in order to efficiently utilize the existing enterprises for increasing the productivity and profitability of the farm. These farm enterprises are crop, livestock, aquaculture, agro-forestry and agri-horticulture.

Integrated farming system is one where more than one agricultural activity is practiced in the same farm unit, the activities being interrelated and competes for the same set of available resources in the farm.

Need

The population in most tropical countries is increasing leaps and bounds, warranting more production of food from limited cultivated lands. Many challenges are faced in our quest to achieve sustainable food security with shrinking land resources for agriculture to produce additional food grains to meet the requirement of the prognosticated population in our country. Furthermore, as agriculture becomes more intensive, soil and waste degradation threaten the sustainable agricultural production. India would need to produce additional food grains of 100 and 160 million tonnes by 2030 and 2050 AD, respectively, to feed its projected population.

India's population as on date is about 1003 million and is expected to reach 1370 and 1600 million in 2030 and 2050 AD, respectively. Food grain production in India reached an all time high of 218 million tonnes during 2000 - 01 and 289 and 349 million tonnes are needed to meet the demand of the projected population in 2030 and 2050 AD, respectively. The current net cultivable area of 142.8 million ha is likely to dwindle further by virtue of diversion of some of the cultivable area to buildings and industrial purposes. It is anticipated that the land area available for cultivation in 2050 would be 137 million ha.

Thus, our production of food grains per unit area almost has to double from what we are obtaining today. This could be made possible by putting the land, both irrigated and rainfed under intensive cultivation. Fortunately, most of our states lie in tropics and so are blessed with abundant solar energy thus making cropping possible round the year. The only way to increase agricultural production is to increase the productivity per unit area per unit time. In the scientific era of agriculture, cropping systems, genotypes, geometry of planting and management practices are designed to increase the productivity per unit area per unit time, simultaneously making efficient use of available resources and stabilizing yields.

The average holding of a farm in India has been declining and as indicated earlier over 80% of operational holdings are below the size of 1.00 hectare (Mahapatra and Bapat, 1992). There is no scope for increasing the farm size, because of steady increase in population with shrinkage of cultivated land as a result of industrialization and urbanization. Only vertical expansion is possible by integrating appropriate farming components requiring lesser space and time ensuring periodic income to the farmer. The integrated farming systems, therefore, assumes greater importance for sound management of farm resources to enhance the farm productivity, reduce the environmental degradation, improve the quality of life of resource poor farmers and to maintain the sustainability. Hence, the sustainable farming systems, economically viable and ecologically compatible encompassed with higher productivity to meet the present and future needs without jeopardizing the potential, are to be optimized for specific agricultural domain.

Principle

- To identify the constraints in increasing farm productivity

- To provide technological intervention options for improving farming systems at a given resource base through farmer participatory research

- To conduct farmers participatory research in refining technologies of farming systems and provide feed back of farm problems to on-station researcher

- To monitor the impact of component or system related technology on sustainability of farming systems to meet the growing needs of population with emphasis on equity and gender issue.

Factors governing choice and size of enterprises

Farming system includes not only crop but also other allied enterprises. The different enterprises have their own characteristics, behaviour within themselves and also have differential behaviour with other enterprises. Hence a careful study on the choice and size of enterprises has to be made before fixing IFS.

Factors influence choice and size of enterprises

Environment

Natural
Social
Political
Economical

Resources

Available within the farm
Available from outside

Farmers

Constraints
Objectives
Attitude
Knowledge
Skills

Technology

Availability
Innovation
Institutional support

Environment

Natural

This includes climatic factors. Based on the climatic factors, choice of crops, size and allied enterprises can be determined. In heavy rainfall area rice + fish or rice + homestead gardens can be associated.

In moderate rainfall area, where supplementary irrigation is essential, cotton, millets, oilseeds, pulses + dairy or cotton, millets, pulses + poultry can be integrated.

In dry lands → Cotton + dry land horticulture + goat (or) Cotton + forage crops with agroforestry + dairy can be integrated.

Size of allied enterprises will be based mainly on soil fertility status, soil moisture storage (dry land only), area of crop component etc. If the fertility status is good, productivity of fodder can be increased per unit area and more number of poultry/dairy can be accommodated.

Eg. In dry land if soil moisture storage is good forage grasses viz., Cenchrus glaucus, Denanath grass and forage millets like sorghum (CO 27, CO 29), Bajra (CO 8) can be raised for green fodder purpose.

Similarly, if the area under paddy is large, mushroom enterprise area can be increased.

Dryland dominated by wasteland should have enterprises like sheep. In degraded soils, agroforestry should be a component system.

Social factor

Size and nature of enterprises is based on the traditional belief in the society, food habits, community decision, social acceptability and inheritance law on farm size.

(eg) Whenever people are fond of native poultry egg, allied enterprises of poultry comprising of exotic poultry breed will not be successful.

Similarly, in areas where beef is not taken in the diet growing of piggery will be failure.

Similarly, any new venture should be socially acceptable (eg) starting of Japanese quail farm was not successful.

Economical

Price of input, output, price support policies affects the profitability of an enterprise and therefore, their choice and size in IFS is important.

Political

Political decision taken on agricultural policies, international policies affects the choice of enterprises in a farming system.

(eg) Prawn farming was encouraged previously but now there are some restriction imposed due to the environmental hazards.

Resources

Within the boundary set by the environment, resources are the inputs required into the system from within or outside for the functioning of various component activities.

Resource	Within	Outside
Land	Area, water from well	Water from tanks and canals
Labour	labour Family , farm animals	Hired human and bullock labour
Implement	Farm implements (country plough hand hoe)	Hand hoe for weeding sickle for harvest ridger, bund formers etc.
Machinery	Power tiller, sprayer, tractors	Power tiller, sprayers combined harves ters, tractor, thresher on hire
Input	Own seed, FYM, green fodder, dry fodder	Seed from Other sources, fertilizer, chemicals, cattle feed.

The quantity and quality of these resources and their sufficiency / deficiency or non availability have considerable influence on the choice of enterprises and relative size in a farming system.

Farmer

Within the same environment with similar resource availability, choice and size of enterprises in farming system may vary from farm to farm based on the knowledge of the farmers about the allied enterprise, skill required for successful implementation of enterprise and his objective and attitude to farming system.

Effect of technology

Introduction and successful implementation of a component entirely depends on the availability of technology about the component, strength of transfer of technology, innovations and new concepts which affect the choice and activity of the component.

Lecture 10. Scope and advantages of integrated farming system.

Agricultural development has undergone profound changes during the last two centuries. In western countries, machine power replaced animal power, fertilizers replaced organic manures. Dominance of fertilization, herbigation were noticed. Similarly in India, during the past four decades, crop improvement, improved production technologies, crop protection technologies were introduced. However, all these development activities were confined to agriculturally intensive 44 districts of our country. The improved technologies pose problems like

- High cost of inputs
- Fluctuation in market price of farm produce which does not commensurate with high cost of cultivation
- Environmental pollution Eg: Nitrate accumulation in Indus river.
- Soil degradation due to depletion of major secondary and micronutrients
- Low level of government support by way of giving subsidy to the farming community.

Technologies developed for individual crop became economically not viable and sustainable. Hence the farmer has to link two or more allied enterprises to enhance or improve his income. In this context farming system play a vital role.

Similarly drylands which constitute 99 million hectare and dryland farmers who are mostly marginal and small farmers (70% of farmer) face many problems.

- Due to uncertain rainfall the yield and income from the crop is uncertain
- The farm labourers are underemployed as the crop season is confined to four months only.
- Natural resource degradation i.e. soil and nutrient loss due to water and wind erosion.

Under such situations the farming system approach forms the only solution to the poor marginal and small farmers of India.

Advantages of Integrated Farming System

a. Productivity

Integrated Farming System provides opportunity to increase economic yield per unit area per unit time by virtue of intensification of crop and allied enterprises. Time concept by crop intensification and space concept by building up of vertical dimension through crops and allied enterprises are the ways to increase productivity.

b. Profitability

The system as a whole provides opportunity to make use of the produce/waste material of one component as input on another component at least cost. Thus, by reduction of cost of production of component profitability per rupee invested are being enhanced. Interference of middleman in most of the inputs used could be eliminated and there by benefit - cost ratio is increased.

c. Potentiality / Sustainability

Of late with an enthusiasm to produce more and more within the land area available to meet the requirement of additional population recorded at 2.2 % every year huge quantum of inorganic fertilizers, inorganic pesticides, fungicides, herbicides etc., are dumped. Thus, there is every likelihood of soil and environment becoming polluted. In IFS organic supplementation through effective utilization of by-products of linked components as manures is possible and thus it will certainly provide an opportunity to sustain the potentiality of the production base viz., soil for much longer periods.

d. Balanced food

In IFS, components of varied nature are linked enabling to produce different sources of nutrition viz., protein, carbohydrate, fat, minerals, and vitamins etc., from the same unit area. This will provide an opportunity to solve the malnutrition problem that exists in the diet of the Indian farmers.

e. Pollution free environment

In the process of production in the crop based activity, some of the organics are left as waste material and such materials when ignored as such will pollute the environment on decomposition. Similarly, application of huge quantity of fertilizer, pesticide, fungicide and herbicide pollute the soil, water and environment to an alarming level. In the case of Integrated Farming System, waste materials are effectively utilized by linking appropriate components and thus utilizing the by-products as organic manures. Similarly by adopting bio control measures will help in preventing pollution of soil, water and atmosphere. In areas where piggery is a major activity, dumping of pig dung gives out huge quantity of unwanted gas and pollutes the atmosphere in the longer run. In IFS, the pig dung is used in the biogas unit to produce bio energy for the utilization of lighting, lifting water from the underground source and for running incubation unit of the poultry farm. Thus, IFS absolutely helps in avoiding environmental pollution.

f. Recycling

IFS establish its stability due to effective recycling of produces/waste materials of any one of the component as input on the other component linked in the programme. Thus, by way of recycling their own material at the farm level, the farmer could be able to reduce the cost of production which enables ultimately to increase the net income of the farm as a whole. Moreover, it also helps in reducing the environmental pollution expected out of decomposition of organic residues of the farm activity.

g. Money round the year

Unlike conventional crop activity where the money is expected only at the time of disposal of the economic produce received after five to fifteen months depending upon the duration of the crop, the IFS provides flow of money to the farmer round the year by way of disposal of eggs, milk, edible mushroom, honey, cocoons of silkworm, etc.

h. Adoption of new technology

Most of the big farmers are fully aware of the impact of new technologies included in the package. But, more than 80 per cent of the farmers who have been grouped under small and marginal categories are not able to execute the advanced technology proposed for want of money. But to IFS farmers, because of the linkage of Dairy/ Mushroom/Sericulture/Fruit crops/Vegetables crops/Flower cultivation, etc., money revolves round the year by sale of produce from these components at weekly/fortnightly interval. Availability of cash round the year gives a sort of inducement to the small and marginal farmers to go for the adoption of technologies like fertilizer application, pesticide and herbicide application given in the package which otherwise is not possible under conventional farming due to paucity of funds.

i. Solve energy crisis

It is expected that the entire world is going to suffer for want of fossil fuel from 2030 AD. So it becomes inevitable to identify an alternative source to solve our energy crisis within a span of 3 to 4 decades. In IFS, by way of effective recycling techniques the organic wastes available in the system can be utilized to generate biogas. Though this may not be a source for complete supplementation, at least to certain extent the energy crisis anticipated can be solved.

j. Solve fodder crisis

In IFS, each and every piece of land is effectively utilized. Growing of perennial fodder trees in the borders and water courses is a recommended practice in IFS. This practice not only helps in supplementing legume fodder but also enriches soil nutrient by fixing the atmospheric nitrogen. In the cropped land also IFS envisages intensification of cropping by including legume fodder like cowpea either as second tier or as third tier in the system. These practices will certainly relieve the crisis of non-availability of quality fodder to the animal component linked.

k. Solve fuel and timber crisis

The national demand of fuel wood in 2020 AD is 400 million m^3, where as the current production is only 20 million m^3. Similarly, the requirement of industrial wood in 2020 AD is 64.4 million m^3 and the current production level is just 11 million m^3. The present level of production should be increased to twenty folds in case of fuel wood and six folds in industrial wood. This could be possible to certain extent by afforestation programme in the shrub jungles and sparse forest areas. In IFS by linking agro-forestry appropriately, the production level of fuel wood and industrial wood can be enhanced without detrimental effect on crop activity in the field level.

l. Avoid degradation of forests

There is a vast gap between the demand and production level as far as fuel wood and timber are concerned. This will naturally induce the users to encroach on the forest area nearby illegally to bridge the gap. Right now our forest area is less (22%) than the prescribed norms (33%), to the geographical area available. When such encroachments are encouraged, there is every possibility of our forest area going to be a wasteland in the years to come. Even in the forest area available at present more than 2/3rd is sparse forest. The statistics on soil erosion indicates that every year 5374 million metric tones of built up soil is eroded in our country every year. This is four folds higher than the prescribed norms viz., 4 mt ha^{-1} $year^{-1}$. By linking Agro-forestry in IFS, the degradation of forest area could be minimized to certain extent by supplementation of fuel and timber wood. By way of preserving the natural eco-system in the catchment areas, precious built up soil can also be preserved from erosion danger.

m. Employment Generation

Combining crop enterprises with that of livestock to take advantage of complementary and supplementary relationships between them, would increase the labour requirements tremendously and can help in solving the problem of underemployment to a great extent. IFS provide enough scope to employ family labour round the year.

n. Improves literacy

The farmers, who adopt IFS by combining different components like fishery, sericulture, mushroom cultivation, apiary, spawn production, dairy, poultry, agri-horticulture, agro-forestry, biogas production, etc, get expertise in each and every aspects of individual component on long range adoption. This will help the farmer to face any challenge in their activity.

o. Provides opportunity for agri-oriented industries

When once the produces of different components linked in IFS are increased to commercial level and if there is glut in the market, leads to the development of allied industries for preserving the by-products.

p. Increase input efficiency

The IFS provides enough scope to use the inputs on different components very effectively. This again leads to increased benefit - cost ratio.

q. Improves the standard of living of farmers

When once provisions are made in the farm level to generate bio energy, produce edible mushroom, fruits, eggs, milk, honey, vegetable, etc., for the family use of the farmer apart from commercial purposes through IFS, create a sort of feeling among the farmers that they are no way inferior to other professionalists in the region. When they feel that their standard of living is on par with others and this will act as a booster tonic to continue agricultural profession without any reluctance which exists at present among most of the farmers.

Scope

- The rising cost of energy
- The low profit margins of conventional practices
- Development of new practices that are seen as viable options
- Increasing environmental awareness among consumers, producers and regulators
- New and stronger markets for alternatively grown and processed farm products
- 44 out of 453 dist contributing half of the total food grain
- No further scope for horizontal expansion of land for cultivation

Advantages of Sustainable Farming System

- Effective and efficient utilization of resources available
- Relies mainly on resources within the agro ecosystem by replacing external inputs
- Manages pests, diseases, and weeds instead of controlling
- Shifts from nutrient management to recycling of nutrients
- Preserves and rebuilds soil fertility, prevents soil erosion, and maintains the soil's ecological health

- Has minimal negative effects on the environment and release no toxic or damaging substances to the system
- Uses Judiciously water in a way that allows recharge of aquifers & meeting water needs of environment and people
- Incorporates the idea of long term sustainability in to overall agro ecosystem

Lecture 11. Allied enterprises for wetland, irrigated upland and dryland - selection and management and their interaction.

i) Possible Components in IFS

Wetland	Garden land	Dry land
Cropping	Cropping	Cropping
Fishery	Milch cows	Goat
Poultry	Buffalo	Agro
forestry		
Pigeon	Bio gas	Horticulture
Goat	Spawn production	Tree
Duck	Mushroom	Pigeon
Pig	Homestead garden	Rabbit
Mushroom	Silviculture	Farm pond
Fodder	Sericulture	Fish

ii) Possible integration in different systems

a) Wetland ecosystem

i) Crop + Fish + Poultry
ii) Crop + Fish + Duck
iii) Crop + Fish + Pigeon
iv) Crop + Fish + Poultry/pigeon + mushroom
v) Crop + Fish +Mushroom
vi) Crop + Fish + Pig + Mushroom
vii) Crop + Fish + Goat

b) Garden land ecosystem

i) Crop + Dairy + Biogas
ii) Crop + Dairy + Biogas + Sericulture
iii) Crop + Dairy + Biogas + Fishery
iv) Crop + Dairy + Biogas + Homestead garden + Sylvipasture
v) Crop + Dairy + Biogas + Homestead garden + Silviculture + Apiculture.
vi) Crop + Dairy + Biogas + Spawn production + Mushroom
vii) Crop + Dairy + Biogas + Spawn production + Mushroom + Silviculture

c) Dry land ecosystem

i) Crop + Goat
ii) Crop + Goat + Agroforestry
iii) Crop + Goat + Agroforestry + Horticulture
iv) Crop + Goat + Agroforestry + Horticulture + Farm pond
v) Crop + Goat + Buffalo + Agroforestry + Farm pond
vi) Crop + Goat + Pigeon + Buffalo + Agroforestry + Farm pond
vii) Crop + Goat + Rabbit

IMPORTANT COMPONENT DETAILS

I. Composite fish culture

i) Preparation of ponds

Before stocking pond should be cleaned (aquatic vegetation, predator, weeds and excessive silt). The methods recommended are

- To clear dense vegetation, apply 2, 4-D Sodium slat
- Release of adequate numbers of Grass carp to control variety of weeds such as duck weed, Hydrilla, grass weeds
- Dewatering the pond. This is possible during summer months.
- Pond embankments should be strengthened to prevent entry to predatory fishes.
- Mahua oil cake to clear unwanted fishes. The toxicity remains for 15 days.
- After 15 days, release of fingerlings should be done.

ii) Pond fertilization

Organic and inorganic nutrient requirement

Mahua oil cake : 200 kg / ha
Cow dung : 10000 kg/ha
Super phosphate : 250 kg/ha
Quick lime : 500 kg/ha

The nutrient status for the actual pond area (10 cents)

Stocking of fingerlings: 10,000/ha (local carp and exotic carp alone)

S.No	**Species**	**Mobility/ Feeding**	**Stocking density (No)**	**Stocking density (%)**
1.	Silver carp (*Hypohthalmichthys molitrix*)	Surface	80	20
2.	Catla (*Caltla catla*)	Surface	80	20
3.	Rohu (*Labeo rohita*)	Column	80	20
4.	Mirgal (*Cyprinus carpio*)	Bottom	60	15
5.	Common carp (*Cyprinus carpio*)	Bottom	60	15
6.	Grass carp (*Clenopharyngodon idella*)	Grass	40	10

Supplementary feeding

Rice bran : 40%
Maize flour : 40%
Oil cake : 20%
(or)
Rice bran : 50%
Oil cake : 50%

II. Mushroom

Mushroom cultivation is an important component in Integrated Farming System. It can be profitable in areas where agricultural residues are abundantly available. Mushroom can be made as profitable agribusiness particularly for small and marginal farmers, landless labours, unemployed youth and young entrepreneurs.

Mushroom is a fungal fruiting body, technically called as sporophore, which produces and disseminates large number of spores, called needles of this plant. Like other fungi, it lacks chlorophyll and hence, it cannot produce its own food and depends on other living or dead plant for its food.

Large number of mushroom grow wild in nature, while many are edible, some are mild to deadly poisonous. Edible mushroom occur during rainy season and used as delicious food. More than 10,000 sp. are used as food in the world and about 70 sp. are suited for artificial cultivation mushroom is cultivated in indoor so very little area is required. In India three type of mushroom are cultivated.

1. Paddy straw mushroom - Valvariella volvacea
2. Oyster mushroom - Pleurotus sp.
3. European or button mushroom - Agaricus bisporus

Growth conditions of different mushroom

Name of mushroom	Crop Cycle (days)	Temperature (^{o}C) Spawn running	Temperature (^{o}C) Cropping	Humidity (%)	Substrate	Bio-efficiency (%)
Paddy straw	24	24	30-36	80-90	Paddy	10
Oyster	35-40	20-30	20-30	75-90	Paddy	10-100
White – Grey mushroom	40-45	20-30	20-30	75-90	Paddy	40-100
Button mushroom	90	21-23	14-15	85-95	Paddy/ Wheat	40-100

(Oyster mushroom cultivation is simple and widely cultivated)

Cultivation

Agricultural waste or by products of agricultural industry can be used as base material.

Eg. Paddy straw, paper waste, sugarcane bagasse, cotton waste, hulled maize cobs- substrate, Saw dust, coir pith, dried flowers, Bajra, sorghum stalk.

Spawn running room

Spawn running room is one where the beds are kept for proliferation of mushroom fungus mycelium in the bed. An ordinary room/thatched shed can be used. Multi-tier racks may be arranged and beds are arranged in each tier. This room not requires light but needs ventilation. Temperature should be between 24-30^{o}C.

Approximate space required for cropping and spawn running rooms

Mushroom production	Spawn running room	Cropping Room	No. of beds/day	No. of racks (80 beds /rack)
1 kg	8 m^2 (4 x 2)	8 m^2	4	2
5 kg	40.5 m^2 (13.5 x 3)	40.5 m^2	20	10
20 kg	162 m^2 (27 x 6)	162 m^2	80	40

The height of thatched shed should not exceed 4 mt.

Cropping room

This requires relatively cooler temperature than spawn running room. The temperature should be between 23-25^{o}C in plains, cropping room should have a door and ventilation. In plains, floor may be filled with sand to a height of 30 cm. All side should be lined with hanging gunny. Floor and gunny should be wetted with water twice a day. This will help the room cooler and increases humidity. Shed may be laid in E-W direction to avoid, direct effect of sun and to reduce temperature inside cropping room.

Materials required

Paddy straw : (Fresh, dried, not more than 6 months old, spoiled straw and cattle fed not suitable)
Chaff cutter
G-I drum - for boiling
Cloth/gunny bag: to spread the straw

Polythene bag : 60 x 30 cm wide
80-100 guage thickness.
Open on both sides for bed preparation
Hand sprayer, polythene bags (20 x 15 cm packing) wall thermometer, spawn bottle (300 gm used for 2 cylindrical bag), iron rod, plastic tray, jute thread.

Preparation of beds

Cut paddy straw 3-5 cm size using chaff cutter.
Soak the straw in hot water for 4-6 hours
Remove and kept in wire basket to drain water for 30 minutes
Boil water in G.I drum and keep the pre-soaked straw immersed in boiling water for about 30 minutes. By this process micro organism, insect, larvae and eggs and insects are destroyed.
Tie around the mouth of the drum with cloth or gunny bags and keep the vessel in tilled position to drain water.
Remove the straw and drain water by keeping in wire basket. Spread the straw in a clean cloth (Cloth previously should be soaked in fungicide solution of 5 gm Bavistin + 10 g Dithane M-45 in 10 lit water or 1 % $KmNo_4$ solution)
Allow the straw to loose excess moisture.

Paddy straw should contain optimum moisture. (Excess moisture lead to bacterial contamination and rotting of straw. Low moisture will not permit the mushroom production)

1 kg dry paddy straw when processed will approximately weigh 50kg.

Each cylindrical bed require 2.5 kg of wet straw approximately equate to 0.5 kg dry straw.

Polythene bags

Size-60 x 30 cm. Make two holes of 1 cm diameter in the centre on each side. Tie the bottom of the bag with jute thread. This provide flat circular bottom of bed when prepared.

Spawn

Clean plastic tray, hooked iron and hand with phenol (detttol-1ml in 100 ml of water). Remove the cotton plug and insert the hooked iron rod into bottle and remove the spawn. Collect the spawn in tray and break the solid and spawn with fingers to individual grains.

Spawning the bed

Spread the straw bits uniformly in the bottom of polythene bags to height of 5cm

Sprinkle one portion of spawn (out of a portion) uniformly over the entire surface of straw.

Spread second layer to height of 10 cm, and sprinkle second portion of spawn. When every layer is put gently jerk the polythene bag for uniform pack straw.

Third layer of straw to a height of 11cm and sprinkle third portion spawn.

Fourth layer 10cm and sprinkle fourth portion

Finally, cover the fourth layer of spawn with straw bits to a height of 5 cm and tie the bag with jute thread.

Bed ready for spawn running room

All the above should be done in a clean room

Spawn running and opening of beds

Keep the cylindrical bed in a spawn running room provided with racks.

Observe the growth of fungus as it grow as a white thread and spread on entire bed

Spawn running will complete in about 15-20 days.

Open the bags by cutting with sterile blade 10^{th} (White oyster) – 21^{st} (Grey oyster) day for oyster mushroom

Cropping

Transfer the open bed to cropping room

For 2 days no need to spray water on beds.

Afterwards spray water on beds every day in morning and evening using a sprayer.

Appearance of mushroom buds (pin head) on third / fourth day of opening beds

Full grown mushroom develops within 3-4 days of appearance.

Harvesting

Pluck full grown mushroom with roots early in morning before spraying water.

After first harvest, scrap and remove 1-2 cm deep layer of straw from entire surface of bed.

Continue spraying of water twice a day, second crop of mushroom appears in another week.

2-3 crops can be over in about 35-40 days for white and 40-45 days for grey oyster. Harvested mushroom should not be wasted in water.

Packing and storage

After harvest remove straw bits and rot portion
Pack the cleaned mushroom in perforated polythene bags
Self-life is 12-16 hours at room temperature
Stored for about 3 days in refrigerator

III. Poultry

It is integrated in IFS mainly for nutrition and employment and to meet out the meat and egg requirement of family.

According to industry sources, the annual output of broilers has multiplied to six folds in the current decade and annual egg production would reach a level of about 22,880 million. Thus annual rate of growth accounted to 20% for broiler and 10% for eggs. India ranks the worlds 5th largest egg producing country but in terms of per capita availability, it would rank the lowest per capita of poultry products currently estimated at less than 30eggs and 100 g poultry meat per year.

A mature bird of good stock lays in a year 14 kg of egg numbering about 250 which is 8-9 times its body weight.

Similarly a good broiler in 6-7 weeks attain a weight of 1.4-1.7 kg with feed conversion ratio of 2.2-2.3. The capital investment/bird in a layer farm averages Rs.80, in broiler Rs.55.
The net profit amounts to Rs.1.50/layer/month
The net profit amounts to Rs.2.00/broiler/month

IV. Apiculture

Honey bee are popularly known as 'angels of agriculture' since they are instrumental in increasing the productivity of number of agricultural crops through cross pollination.

Benefits

- Pollen germination is stimulated
- Rate of fertilization is increased
- Fruit/seed set is enhanced
- Fruit quality is improved
- Oil content in seed is increased

Thus it is helpful in increasing productivity both qualitatively and quantitatively.

- They yield useful products like honey, bee pollen, bee venom, royal jelly.

- Yield potential of cross pollinated crops can be achieved only when pollination requirement of the crop is fulfilled. Hence, honeybees should be used as an important input to achieve maximum yield. In Integrated farming system 5-6 honey bee box/ha is recommended.

U. Biogas

It is one of the alternatives to alleviate energy crisis in the farm sector. In addition it gives good quality manure devoid of weed seeds. About 208 million kg of dung is available per day and it is possible to produce 8.4 million m^3 of biogas / day. But only 7% of dung is utilized for biogas production. About one lakh biogas plant of 4 m^3 capacity each requiring about 100 kg of dung/day could be possible with the available manure in the state. Apart from cattle dung, wastes from birds, sericulture, goat, field wastes can be used for biogas production. From cow dung which comprises of 60 % methane and 40% of CO_2 was used as a fumigant in specially designed air tight bin of one quintal capacity for the control of storage insects of pulses in seeds and grains of pigeon pea.

Three jersey cross breed milch cows with 2 calves can be included as component under Integrated farming system. For effective recycling of farm and animal waste a bio-gas unit of 2 m^3 capacity can be installed for the production of fuel, light and enriched manure. Sixty kg of cow dung expected out of 5 animals is sufficient enough to produce 2 m^3 of gas every day which is equivalent to 1.5 litres kerosene. By this recycling, some of the weed seeds present in the raw cow dung also get killed during digestion process, thus improving the quality of the slurry over its raw material used viz., cow dung. The quality improvement by way of recycling the cow dung through bio gas chamber was studied by analyzing the NPK content of slurry and FYM prepared utilizing the cow dung from the system. Recycling of 730 m^3 of biogas with the possibility of enhancing the nutrient value of NPK to the tune of 44.5 kg, 65.9 kg and 28 kg respectively in a year. The calorific value of biogas is 3600 k Cal m^3. Bio gas can be used for cooking, lighting and as a substitute for diesel. Digested slurry from the biogas plant is a superior organic manure as it has narrow C:N ratio, low per cent of weed seed and colour less.

Biogas plant size is decided based on number of animals and quantity of dung.

No. of cattle	**Dung (kg/day)**	**Family size**	**Size of biogas plant (m^3)**
3-4	40-50	4-6	2
4-6	60-75	7-8	3
6-8	80-100	10-12	4
10-12	120-150	16-18	6

Nutrient gain by recycling (kg)

Particulars	N	P	K	Fe	Mn	Zn	Cu
Nutrient in biogas Slurry (11t on dry wt. basis)	157.30	133.10	144.40	46.20	6.05	1.65	0.57
Nutrient in FYM (11.6t) in an year	112.80	67.20	86.40	44.00	5.39	1.10	0.49
Nutrients gained by way of Recycling	44.50	65.90	28.00	2.20	0.66	0.55	0.08

(Rangasamy, 2000)

VI. Dairy farming

Importance

- It could provide constant income throughout the year
- Success depends on availability of feed and fodder
- Marketing facilities to milk

Variety

Jersey cross bred cows

- suitable for all climate
- consumes less feed and fodder
- give more milk with high fat
- possess better disease resistance

Holstein Friesian cross

- reared for higher milk
- require cooler climate

Buffalo (Murrah)

- Digest more of roughages and thrive well on dry fodder
- Buffalo contribute 60% milk to national milk grid
- Higher profit can be obtained

VII. Sheep and goat rearing

Sheep population has declined from 95 million to 61.7 million heads. But there is an increase in goat population from 65 million to 105 million heads, despite of discouragement to goat rearing.

Limitation in sheep rearing

Pressure on land for crop production Greater incidence of sheep diseases. Inadequate housing facilities

Small and marginal farmers could maintain 20 animals and land less labourers 5 animals with available fodder in the village.

Goat rearing- advantages

1. Thrive on several type of foliage and fodder
2. Hardy and disease tolerant
3. Give multiple kids
4. Faster growth
5. Excellent market facilities
6. It can be reared by rich and poor
7. Income without much input
8. Scarce commodity for rare ayurvedic medicines and human diet
9. Important role in rural economy
10. Helps farmers at the time of crop failure
11. Good profession for the weaker section of rural people in drought prone, hilly and desert area.
12. Provide employment for under and un employees, small, marginal farmers and landless agricultural labourers.
13. Provide milk and meat for poor
14. Highly adoptable to extreme and different agro climatic condition.

Suitable breed for intensive system - Tellicherry, Jamunapari. They require less space, better growth rate and more return. In intensive system, farmer could get Rs.800 – 1000 from each female in a year by selling 2 kids and manure. In an acre 40 goats can be maintained by growing high yielding fodder grass and tree. About Rs.12000-15,000 could be realized from the unit as net profit. If family labour is engaged net profit could be 15,000 – 18,000 / year.

Goat rearing is mostly followed by small and marginal farmers. Goat rearing is considered to be mortgage lifter and mobile bank.
Per capita availability of meat is very poor in India
India : 6 gm / person / day ; 57 gm / person / day in world Goat milk constitutes 2.4% of world total milk production

VIII. Piggery

Pig exceeds other livestock by its efficient feed conversion and prolificacy in reproduction. Helps in improving the animal protein requirement. About six million pigs are available in India. Pig meat is available at lower cost. Important variety is large white Yorkshire breed.
Maturity age: 7 months
Female produces 9 – 10 piglets in one furrowing
Birth weight : 1 – 2 kg / piglet

IX. Rabbit

Rabbit broiler production gained momentum in past few year
in Tamil Nadu
Rabbit meat rich in protein, fat and fibre
Variety :White grey, black brown, California white, New zealand white, Zealand red, Soviet chinchilla, Great giant
Feed : Rabbit are herbivores which consumes different type of green roughages like berseem,lucerne,cowpea,grasses and weeds, root crops like carrot, turnip.
Feed requirement : 50 - 150 gm concentrate feed, 50 – 70 gm vegetable and 150 - 200 gm green fodder.

X. Ducks

Raised for eggs and meat. Some places, it is kept for ornamental purposes

Variety : Indian runner, khaki Campbell
Weight : 2 – 2.5 kg
Green feed : Berseem, Lucerne. Normal feed ingredients used for poultry is recommended.

XI. Pigeon

Pigeon meat is popular mostly in Europe and USA
Pigeon meat : 26 – 30 days. Wt. 500 gm
Popular breed : Red cannier, white king, king breed, red, blue, dark king
Adult weight about 750 – 800 gm

Breeding

A pair of pigeon produces 12 marketable squabs in a year with a average wt. of 500- 700 gm. Female starts laying at 6th month. Females have breeding life up to 10 years. Males used successfully up to 5 years

Differentiation

Female smallest with fuller heads and it tends to waddle rather to walk and holds the fail slightly higher up. Male bigger, more aggressive and makes low voice
Incubation : 17 days
Squab hatches on 18 – 19th day
Female birds start laying again when squab is 2 weeks of age **Nutrition :** Fed with small whole grains like maize, sorghum, cumbu, green gram, ragi

INTERACTION BETWEEN COMPONENTS

Rice cum fish culture

This is commonly practiced in coastal areas in the states of Kerala and West Bengal.
This system has great scope in West Bengal, Assam, Bihar, U.P, Orissa and A.P. where only single long duration rice crop varieties are cultivated.

Central Inland Fishery Research Institute (CIFRI) have indicated that fresh water fishes can be cultivated in paddy fields with ponds constructed within the paddy field. Two crops of tall variety of rice (deep water variety) in kharif and HYV (dwarf) in rabi are possible and single crop of fish covering both the seasons can be raised.

Types of Trenches suitable for Rice + Fish system

1. Perimeter type
2. Central pond type
3. Lateral trench type

Depth : 1 mt. – 1.5 mt.

Suitable composite fish culture (catla, rohu, mirgal, common carp) Area for fish pond : 1/10th of rice field

Pest control: pesticide like neem based pesticides, carbonates and selective organophosphates may be used in low doses.

When rice crop harvested during Nov. – Dec, the water recedes from rice field and fishes take shelter in the trenches. During rabi, rice field once again prepared and dwarf varieties are planted.

Average fish yield : 700 – 1000 kg / year/ 25 cent fish pond

Financial return : 20% over monocropping

Rice + Duck + Fish farming

Total ducks : 200 – 320 kg (1 kg weight /duck) / ha pond

Manure : 10 – 15 t / ha / year

Manure collected and applied (or) it may be constructed above the water surface of pond

Production : 3000 – 4500 kg meat / year

Two rice + Fish + Azolla + Calotrophis

Rice varieties : ADT 36, ADT 38 during kharif and rabi respectively

Azolla microphylla : 2 t / ha (fish feed cum 'N' fixer) applied at 5 DAT and Calotrophis a wasteland weed incorporated @ 12.5 t/ha as GLM at 10 DAT.

NPK fertilizer : 100 : 50 : 50 kg/ha

Water depth in rice field : 5 cm

Plant protection (Need based) : 5 % Neem Seed Kernel Extract

Fingerlings : Catla, rohu, mirgal in equal ratio

Stocking density : 3000/ha

Stocking time : 15 DAT

Feed: Banana pseudo stem with cow dung 1:1 mixture + Rice bran } 3% body weight of fishes

Depth of fish trenches : 1 mt. depth

Width :1 mt.

Area :10% of rice area to shelter the fishes

Paddy yield :10,125 kg from two rice crop

Net return :Rs.17488/-

Fish yield	:173 kg
Nitrogen gain	:24 kg/ha

Rice – Fish + Vegetable farming

Vegetable crops like bitter guard, ribbed guard are raised along the raised bunds of fish trenches

Yield : (kg/ha)	Rice yield	Fish yield (kg/ha)	Vegetable yield (kg/ha)	Net return (Rs./ha)
Rice – Rice + Fish + Vegetables	10094	407	132	19496
Rice – Rice	10285	-	-	15840

Crop + fish (pond system) + poultry + mushroom

i) Crop : Rice – Rice – Maize Rice – Rice - Groundnut	: 0.90 ha
ii) Fish	:0.10 ha
Fish stocking density	:400 Nos.
iii) Poultry bird	:20 Nos. of layers
Poultry dropping	:2kg / day from 20 birds
iv) Mushroom	:2kg production capacity/day

Fish + Pig farming

Pig site	: Constructed on the embankment of the fish pond
Pig manure	: drained directly to fish pond
No. of pigs	: 2-3
Fish yield	: 250 - 300 kg

Pig manure contains 80% digestible food for fish.

CROP + LIVESTOCK (DAIRY)

Dairy forms an important component in farming system especially under garden land conditions. Crop + live stock farming system is a broad system involving farming system that are suitable for different ecosystem. Crop + dairy will be an important system for garden land area. While crop + poultry is ideal for wet land system and crop + goat, crop + sheep ideal for dryland system. Various interactions (both competitive and complementary) are discussed here.

Complementary interaction

Milch cows produce milk which gives most sustainable income among the income generated from allied enterprises.

Cow dung forms a rich resource of organic manure and can be recycled to the field. Approximately 1.2 tonnes of dry cow dung from each animal can be recycled into the field.

Maintenance of three milch animals can generate enough cow dung and cow dung treated in anaerobic decomposition, bio gas will be released. The bio gas is a mixture of methane, carbon-di-oxide, traces of nitrogen, hydrogen, sulphide, oxygen and ammonia. Methane constitute nearly 60% of volume.

The calorific value of bio gas is 3600 K Cal/m^3. Bio gas can be used for cooking, lighting and as a substitute for diesel. Digested slurry from the bio gas plant is a superior organic manure as it has narrow C:N ratio, low per cent of weed seed and colour less.

Crop by products are used as feed to cattle. Paddy straw is used to meet the roughage requirement. Pulses and groundnut haulms are also used as cattle feed. In garden land conditions wherever sorghum/maize is raised straw/stover can be used immediately after harvest of crops as green fodder.

Competitive interaction

Investment in crop management and dairy management are equally high. The investment in crops is on the cost of tillage, input purchase, labour charges for planting, weeding, harvesting and processing. The investment of dairy involves purchase of feed material like concentrate, labour charges for maintenance and medicine.

Capital on fixed cost is also equally high in both enterprises. In crop enterprise digging open/bore well, energisation of pumps, construction of pre-fabricated channel, thrashing floor and in live stock, construction of live stock shed, feeding trough and purchase of livestock are costly.

Area for green fodder will pose competition to the crop area and for irrigation water.

Similarly in labour scarcity area/period there is competition for labour in both enterprises.

CROP + POULTRY

Complementary interaction

Poultry will reduce the insect population by eating the larvae, destroying egg masses, there by pest damage can be reduced.

Poultry dropping if collected properly can be used as organic manure (poultry manure) and it increases the yield of the crops.

Reports are available indicating low or sparse weed population in the fields supplied with poultry manure.

Poultry dropping becomes useful feeding material for fish grown in fish pond.

Competitive interaction

If bigger units of poultry are maintained there will be competition for capital. Otherwise there is not much competition for capital.

CROP + FISH

Aquaculture is terminology used in South East Asian countries for fish farming. Fish culture is done in larger scale in Thailand, Indonesia. Fish culture is common in West Bengal in India.

Complementary interaction

Rice + fish can be raised on the same field either simultaneously or rotationally. In this case decomposing of rice stubble helps the multiplication of plankton for fish, fish fauna enrich the rice field.

Competitive interaction

There will be intense competition for water by both fishes and rice during summer/dry monsoon period. During this reason alternate crop should be selected.

CROP + GOAT

Crops and goat association is restricted to dry lands. Hence we must plan the enterprises in such a way that higher rate of complementary interaction is achieved. The competitive interaction should be kept under minimum level. For dry land Tellicherry breed is preferable.

Complementary interaction

Milk from goat is very nutritious and can be used for human consumption.

By regular sale of young ones (one or two goat) a regular monthly income of Rs.400-600 can be achieved from one unit goat enterprise (5+1)

Goat litter can be used as organic manure and can be recycled to the field.

Competitive interaction

Very slight competitive interaction for area is observed between goat and crops enterprises. Goat may require feed @ 1.5-2.0 kg green fodder and 100 g of concentrate for a day per animal. For obtaining green fodder/ dry fodder at least 0.20 ha is required. This much area has to be allocated for raising fodder crops/fodder trees and this area can not be used for raising any other dry land crops.

Competition for capital-resource of dry land farmers. He has to invest at least 50% of his economic resource for the purchase of Tellicherry goat, construction of shed etc., hence sufficient financial support is needed. Each goat may cost Rs.1000-1200 and put together 6 goats may cost Rs.6000-7200. Cost of construction of shed – Rs. 5000. Total cost of goat unit is around Rs.12,000.

CROP + MUSHROOM

Complementary interaction

It gives additional income to the farmers

Daily 1.5-2.0 kg of mushroom can be produced by utilizing 5 kg dry paddy straw/day in a mushroom shed with dimension

of 5 x 3 m. This may give an income of Rs. 40.-60 per day.

Competitive interaction

Initial cost involved in shed construction.

CROP + APIARY

Complementary interaction

It gives additional income

Due to the increased activity of bees, cross pollination of crops and better seed setting are achieved eg. Sunflower

Competitive interaction- Nil

CROP + RABBIT

Complementary interaction

Gives additional income to the farmers.

Competitive interaction

Shed cost

CROP + SERICULTURE

Crop + Sericulture will be successful only in upland conditions with irrigation potential. More family labour and skilled labour are needed for successful rearing of silk worm.

Complementary interaction

- Additional income to the farmers
- Dried mulberry leaves can be used as manure. Larval waste and rejects of leaves obtained after silk worm feeding can be used as manure.

Competitive interaction

- Competition for land is high. At least 0.2 ha land is needed for cultivation of mulberry for rearing 100 DFLs / cycle.
- There is competition for water, manures between mulberry and other food crops.

AGROFORESTRY

Agroforestry is an integrated self sustained land management system which involves deliberate introduction /retention of woody components (trees, shrubs, bamboos, etc.) with agricultural crops including pasture, livestock simultaneously or sequentially on the same unit of land meeting the ecological and socio-economic needs of the people. It is classified as

- Agrisilvipasture
- Sylvipasture
- Agrihorticulture
- Agrihorti Sylvipasture
- Homestead Agroforestry

Complementary interaction

Protective interaction

It reduces water erosion considerably by proper planting of tree spp. Wind erosion as well as run off can be checked and erosion can be reduced.

Protection from adverse climate

Controlling desertification and stabilizing sand dunes

Reducing crop loss in Arid and SAT by increasing RH, reducing temperature.

Productive interaction

It supplies fodder, food.

It increases nutrient status in the soil. (eg) Growing legume tree (Rain tree) increases N content while casuarinas enhance N and P content in soil.

Increased organic matter in the soil

Nutrient addition through leaf litter and recycling of nutrients. (eg) Eucalyptus gives 1800 kg of leaf litter per year which on decomposition add 14:10:18 kg of N, P and K to the soil.

Some species give quality timber which can be used for house building

Some species supply raw materials to industries eg. *Ailanthus excelsa*

Appropriate agro forestry does not reduce the yield of agricultural crops

Eg. Neem +Sorghum / Tamarind + Sorghum, Neem + Black gram : Black soil
Casuarina + ground nut : Red soil
Overall income of the farmers increased after 5 years.

Competitive interaction

An ideal agro forestry system should not create competitive interaction. However, under field condition competitive interaction is inevitable if improperly managed.

The following competitive interactions are very common.

1. Wrong choice of agroforestry system may severely hamper the growth of annual crops as the tree sp. will compete for space, light, moisture, nutrient and vice versa.

Eg. casuarina + Black gram/sorghum is not a good choice in deep vertisols as the yield of annual crop is reduced significantly.

Ailanthus excelsa + sorghum is having a depressive effect on sorghum yield.

Ailanthus excelsa + Denanath grass component reduces the growth of tree component.

2. There is chance of occurrence and development of polyphagus insect that may affect both tree and agricultural crops. Eg. Hairy caterpillar in Ailanthus affect the annual crop yield.

3. Allelopathic effect caused by tree spp may affect the crop growth (eg) Eucalyptus effect on annual crops.

Mutual shading effect at very early stage of tree species hampers the annual crop growth.

Lecture 12. Resource recycling in integrated farming system and Resource management under constraint situations

One of the main objectives in the Integrated Farming System is recycling of produces/wastes among the components involved. The end product of such recycled materials are used as organic manures for crop plants. Some of the products are improved in their quality on recycling and thus it provides double benefit to the farmer. A judicious mix of one or more enterprises with cropping, complements each enterprise through effective recycling of waste/residues.

Crop and animal waste utilization

The productivity of livestock mainly depends on the availability of quality feed and fodders in requisite quantity. It is observed that most of the livestock population in the country is underfed. The residues of different agricultural crops constitute the major source of fodder for livestock. In India, till late 1980’s the main source of livestock feed consisted of conventional agricultural residues like rice straw, wheat, sorghum and maize stalks, sugarcane trash and remains from pulses. Based on the grain : straw ratio, approximately 321.4 million tonnes of agricultural crop residues are available in India.

The area under green fodder is not increasing to meet the increased demand. The area under green fodder in the country is estimated to be approximately 4% of the total cultivated area. Since the farmers feel that animal power is one of the costliest inputs, they switched over to mechanical power for most of the operations. Moreover, the animals meant for milk and meat is replaced by cross-bred and improved varieties, which need to be supplemented with quality concentrated feeds. Thus, the estimated total production of crop residues in 2020 AD to the tune of 447.0 million tonnes is to be effectively utilized otherwise. The details of the crop residues in India as given by FAO (1985) projected to 2020 AD are furnished in Table.1.

In addition to crop residues, there is a possibility for collecting the following quantities of animal voids in India (FAO.1985).

Cow dung	750 m.t.
Buffalo dung	250 m.t.
Voids of small ruminants	130 m.t.
Total	1130 m.t.

At present the voids are being utilized for fuel and as FYM/compost. When recycled through biogas unit, there is good possibility to improve the organic source of nutrients apart from generation of fuel energy where tapping of fossil fuel is getting depleted. Apart from the major nutrients there is good amount of enhancement in the availability of secondary and trace elements. By virtue of adoption of one of the modern agricultural technology viz., Integrated Farming System (IFS) in the farm activity, there is a possibility of improving untapped potential of each and every produce by recycling with dual benefits.

Table 1. Projected availability of crop residues in 2020 AD

Crop	**Quantity of residue (million tonnes)**	
	FAO estimate (1985)	**Projected for 2020 AD**
Rice	118.9	160.0
Wheat	57.5	80.0
Maize	21.0	35.0
Millets	40.0	56.0
Sorghum	41.0	52.0
Sugarcane	43.0	64.0
Total	**321.4**	**447.0**

The schematic diagram projecting part of animal voids for generation of bio-energy and utilization of slurry as organic source of nutrients as well as availability of crop residue and recycling for mushroom production and their nutrient value are furnished in Fig. 1 and 2.

Lowland Farming

In the lowland IFS, cropping, poultry, fishery and mushroom enterprises are involved with a view to recycle the residue and byproducts of one component over the other. A trial was conducted for a period of five years (1987- 1982) in an area of 0.4 ha (1.0 acre) considering the average holding size of marginal and small category farmers. In one acre farm, 90 cents were assigned for crop activity and the remaining 10 cents allotted to fish pond. Twenty fowls sheltered over 10 cents of fish pond to feed 400 polyculture fingerlings gave about 700 kg poultry droppings in a cropping year. This could yield about 33.7, 21.4, 10.1 kg of N, P_2O_5 and K_2O respectively. In IFS, at the end of one year after the harvest of grown up fish, about 4500 kg of silt was obtained from the pond with a nutrient content of 3.52, 1.38 and 1.06 per cent N, P_2O_5 and K_2O respectively. The total nutrient content thus worked out to about 158.4, 62.1 and 47.7 kg of Nitrogen, Phosphorus and Potassium. This could relieved the burden of applying equal quantity of inorganic fertilizer to the crop component of the IFS. Even after accounting the nutrient value of the voids of fowls as manure, additional benefit of 124.7 kg, 40.7 kg and 37.6 kg of NPK respectively, can be achieved by recycling (Table 2).

Table 2. Nutrient value of recycled poultry manure

Particulars	**Content (%)**			**Nutrient added (kg)**		
	N	**P**	**K**	**N**	**P**	**K**
Raw poultry manure	4.81	3.06	1.44	33.7	21.4	10.1
Settled silt of the pond in which poultry dropping is used as source of fish feed	3.52	1.38	1.06	158.4	62.1	47.7
Additional benefit through recycling				124.7	40.7	37.6

(Rangasamy, 1996)

Similarly, inclusion of mushroom with the production capacity of 2 kg/day as one of the components in IFS utilizes about 1800 kg of paddy straw and could yield about 2340 kg of mushroom spent after the harvest of edible mushroom at the end of one year. The enhancement in weight in the mushroom spent is due to unharvested mycelial growth. The nutrient value as well as the total nutrient content of utilized straw and the mushroom spent are furnished in Table 3 and Fig.2.

Table 3. Nutrient value of mushroom spent in IFS

Particulars	**Content (%)**			**Nutrient added (kg)**		
	N	**P**	**K**	**N**	**P**	**K**
Paddy straw	0.62	0.24	1.72	11.2	4.3	31.0
Mushroom spent	0.71	0.29	1.74	16.6	6.8	34.6
Additional benefit through recycling				5.4	2.5	3.6

Field experiments were conducted at the Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore to identify and optimize the component linkage for lowlands of Tamil Nadu and to sustain the productivity through effective recycling of wastes from the linked components associated in the system during September, 1993 through August, 1995.

The components of integrated farming systems in lowlands involves crop + fish + mushroom, crop + poultry, fish + mushroom and crop + pigeon + fish + mushroom. The efficiency of the component linkages was evaluated predominantly on the basis of productivity, its income and employment generation with the possibility of utilizing recycled organic wastes as nutrient to enrich the soil fertility.

Experiment on enterprise linkage for low land farming systems revealed that rice-soybean – sunflower and rice-gingelly-maize cropping systems each in 0.18 ha with pigeon (40 pairs) fish (4000 polyculture finger lings in 0.04 ha of ponded water) and mushroom (2 kg day^{-1}) was best in obtaining higher rice grain equivalents than the conventional cropping system being popular with rice-greengram-maize (0.20 ha) and rice-sunnhemp – maize (0.20 ha) cropping systems (Model 1) (Jayanthi, 1995). Cropping + pigeon + fish + mushroom integration earned the highest gross and net returns with better per day returns and benefit cost ratio. Integration of cropping with pigeon + fish + mushroom generated the highest employment of 798 man days/ ha / year with 1.16 man days from the allied enterprises linked with equidistribution through out the year. Integration of poultry + fish + mushroom + cropping applied with recycled poultry manure sustained the productivity of soil through the addition of bio-resource residue with better NPK nutrient supply potential (Model 2).

The growth of fish culture included were comparable among artificial feeding and the treatments with poultry and pigeon droppings feeding. Fish production was higher with artificial feeding than with other two methods (Model 3). However, the net returns and benefit cost ratio were higher in the fish fed with poultry dropping followed by pigeon dropping.

To enhance and sustain the productivity, economic returns, employment generation for the family labour round the year and soil fertility with environmental protection, integration of rice-gingelly-maize and rice-soybean-sunflower cropping each in 0.45 ha with recycled poultry manure as fish pond silt to rice and 75 per cent of the recommended NPK to each crop in the system + poultry (50 layers) + fish (1000 polyculture fingerlings in 0.10 ha of ponded water) comprising catla (20 per cent), silver carp (20 per cent) rohu 20 per cent, mirgal (15 per cent), common carp (15 per cent) and grass carp (10 per cent) fed with poultry dropping + Oyster mushroom (5 kg day) for the lowland farmers having onc hectare farm.

Rice – Fish + Azolla Farming System

Field experiment was conducted at ARS, Bhavanisagar to develop an integrated N management practices for rice – fish - Azolla farming in wetland. Farming systems consisted of rice - rice + fish and rice - rice + Azolla + fish and two levels of N (100 and 75 per cent recommended) with and without green leaf manure (Sesbania rostrata) applications. In the rice - fish system, rice and fish crops were raised together (synchronous system) in rice field. Field trenches were provided with 1.0 m depth and 1.5 m width occupying 10 per cent of the rice area, for sheltering the fish. Azolla microphylla was grown in rice field throughout the cropping period. The dual culture method of growing Azolla with rice has gained widespread adoptability because standing water is available in rice field from seedling to panicle maturity in lowland rice fields and is effectively used as biofertilizer for rice. Azolla cultivation in rice field can improve the fish food. Fish culture in rice fields loosens the soil as a result of their free movement in water body and thus aerating the soil, enhances the decomposition of organic matter and promotes release of nutrients from soil. The excreta of fish directly fertilize the water in rice fields leading to increase in utilizable source of N to the rice crop. Integration of allied components like Azolla + fish with rice in lowland farming could provide wider scope for bio resources recycling (Fig. 3).

Rice - rice - Azolla + fish farming with 75 per cent recommended N as well as incorporation of green leaf manure resulted in higher productivity with increased economic returns and improved the soil fertility through recycling of organic residues. The quantum of organic residue addition and N added through recycling were higher in rice – rice - Azolla + fish farming with Sesbania rostrata incorporation (Table 4). The unutilized fish feed, decayed Azolla and fish excreta settled at the fish trench bottom had a higher nutrient value, which can be recycled to enrich the soil (Balusamy,1996).

Farming in Upland with Supplemental Irrigation

Bearing in mind the advantage of recycling of cow dung, a waste from the animal component (3 adult + 2 calves), biogas unit was linked in the IFS of upland with supplemental irrigation instead of directly utilizing it as FYM. It gave a good proportion of methane gas, a fuel supplement, apart from its enhanced manurial value of the slurry that comes out of the biogas chamber. Moreover, by this recycling, some of the weed seeds present in the raw cow dung also get killed during digestion process, thus improving the quality of the slurry over its raw material used viz., cow dung. The quality improvement by way of recycling the cow dung through biogas chamber was studied by analyzing the NPK content of slurry and FYM prepared utilizing the cow dung from the system. The total quantity secured from the unit over the period of 365 days has been taken on equal weight basis and the analyzed data is furnished in the Table 5 and Table 6.

Table 5. Nutrient content in biogas slurry and FYM

Particulars	Nutrient content						
	Major element (%)			Trace element (ppm)			
	N	P	K	Fe	Mn	Zn	Cu
Biogas slurry	1.43	1.21	1.01	4200	550	150	52
Farm yard manure	0.94	0.56	0.72	4000	490	100	45

Table 6. Nutrient saving by recycling (kg)

Particulars	N	P	K	Fe	Mn	Zn	Cu
1. Quantum of nutrient in slurry obtained (11.0 t on dry wt basis)	157.3	133.1	144.4	46.2	6.05	1.65	0.57
2. Quantum of nutrient in FYM obtained (11.6 t) in an year	112.8	67.2	86.4	44.0	5.39	1.10	0.49
3. Additional nutrient realized by way	44.5	65.9	28.0	2.2	0.66	0.55	0.08

The net income and employment generated through this system were Rs.20,702/ha/year and 620 additional man days ha^{-1} $year^{-1}$ respectively.

Recycling of cow dung also lead to the production of 730 m^3 of biogas with the possibility of enhancing the nutrient value of NPK to the tune of 44.5 kg, 65.9 kg and 28 kg respectively, in a year. Trace elements like Fe, Mn, Zn and Cu are also present in an enhanced level over FYM (Rangasamy and Premsekhar, 1994).

Rainfed Farming

The model integrating Tellicherry goat as component with crop activity in rainfed condition has been tried for a period of five years. The data collected on the availability of organic source of crop nutrients is furnished in Table 7. The organic manures like litter from the goat unit can readily be used for soil application and thus will help in enriching the soil. Goat droppings are found to be a good energy source, which can also be linked with biogas unit before it is utilized as manure. This will generate good volume of gas (22 kg of goat dropping will generate one cubic meter of gas as against 30 kg of cattle dung) as well as enhance nutrient availability. Thus, through recycling of organic in the Farming Systems approach, the potential of each produce can be exploited to a greater extent. Apart form recycling additional net income of Rs.5671/ha/year with 314 man days ha^{-1} $year^{-1}$s were gained through integrated farming system Table 9 (Sivasankaran, 1994).

Table 7. Nutrient gain from 20 + 1 productive Tellicherry goats unit under deep litter system

1.	No. of kidding, $year^{-1}$	1.5		
2.	No. of kids, kidding $year^{-1}$	1.5		
3.	No. of kids, $year^{-1}$, adult	2.25		
4.	No. of kids from 20 adults $year^{-1}$	45		
5.	Mean wt. of dropping recorded day^{-1}	**Adult**	**Kid**	
	(Excludes the pellets dropped during open grazing)	900 g	110 g	
6.	Dropping received in an year	6800 + 1800 = 8600 kg		
7.	Wt. of coir waste used for the stall $year^{-1}$ (50 kg $week^{-1}$)	2600 kg		
8.	Deep litter waste obtained $year^{-1}$	8600 + 2600 = 11200 kg		
9.	Analytical value of deep litter waste obtained from	N	P	K
	the unit	1.79	0.95	0.82
10.	Total nutrient available from the goat unit, $year^{-1}$	200.5 kg	106.4kg	91.8 kg

Resource management under constraint situations - agronomic measures for management of scarce and costly input, delay and insufficiency of water supply

Very often certain inputs, which are very vital in crop production, become scarce in availability due to shortage in supply or increase m demand. Escalation in the cost of such inputs will increase the cost of production. The use of such inputs cannot be dispensed with completely. Under such circumstances, suitable management strategies have to be devised and adopted to fully or partially substitute them with alternate sources and to increase their use efficiency. Fertilizers often come under this category. The following practices are useful in fertilizer management.

- Reduction in quantity of fertilizers based on adoption of soil test recommendations. Reduction in quantity of fertilizers based on cropping system effect.
- Use of alternate source, which is less costly and easily available.
- Integrated use of organic manures to increase fertilizer use efficiency.
- Use of bio-fertilizers for partial substitution of fertilizers.
- Use of nitrification inhibitors, slow release fertilizers to reduce loss of applied fertilizer N
- Suitable method of application to reduce loss and increase recovery of applied nutrients by plants.
- Synchronising the time of application to match peak requirement period of crop to improve uptake and reduce loss.
- Selection of suitable form of fertilizer to prevent loss through fixation, leaching volatalisation, immobilisation, etc.
- Balanced use of nutrients.
- Amelioration of soil physical and chemical problems to improve availability of applied nutrients.

Delay and Insufficiency of Water Supply

Adequate and timely availability of water through irrigation or rainfall is very essential for successful crop production. In irrigated crops, limited water supply from canals, tanks or wells affects crop production. In river command areas, delay in release of water for irrigation may affect many crop management decisions such as time of sowing, choice of crop, age of seedlings at planting etc. In drylands, problems in soil moisture availability arise due to delayed onset of monsoon, early withdrawal of monsoon and intermediary dry spells during cropping season. The intensity of adverse effect on crop growth and yield due to insufficiency of water supply depends on the extent of deficit and the crop growth stage at which deficit occurs. Suitable management decisions have to be then made to avoid or minimise the adverse effect under such contingencies.

In irrigated areas, the strategies to be adopted to include one or more of the following

- Choice of crop /variety with lesser water requirement and tolerance to drought.
- Choice of crop/variety to suit the change in time of sowing.
- Alternate cropping system.
- Changes in land shaping, irrigation methods and irrigation scheduling to suit limited water supply.
- Management practices to minimise the effect of moisture stress eg. seed hardening, anti-transpirants, extra potassium application, mulching.etc.

In canal command areas, water availability may take any of the following patterns and crop planning has to be suitably made.

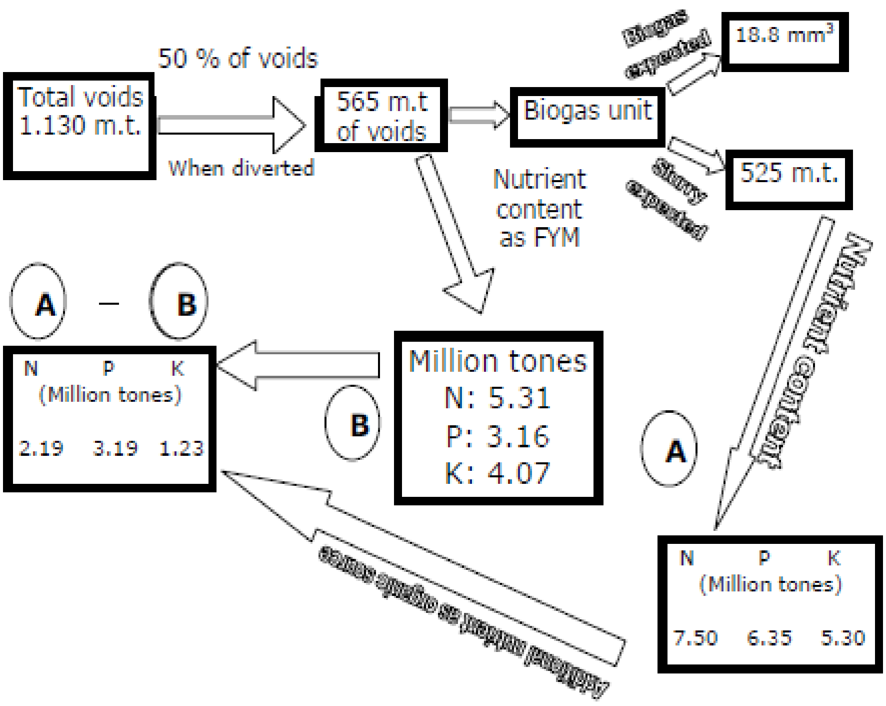
a. Normal release and normal closure of water.
b. Normal release and early closure of water.
c. Delayed release and normal closure of water.
d. Delayed release and early closure of water.
e. Water supply in turn during cropping reason.

In the drylands, where crop production depends exclusively on rainfall abnormal behaviour or aberrations in rainfall affect almost every decision on crop management. Such deviations in rainfall behaviour include

a. Delayed onset of monsoon affecting time of sowing, choice of crop/ variety, cropping system
b. Early withdrawal of monsoon causing moisture stress at crop maturity.
c. Intermediary dry spells during growing season leading to moisture stress at different growth stages.

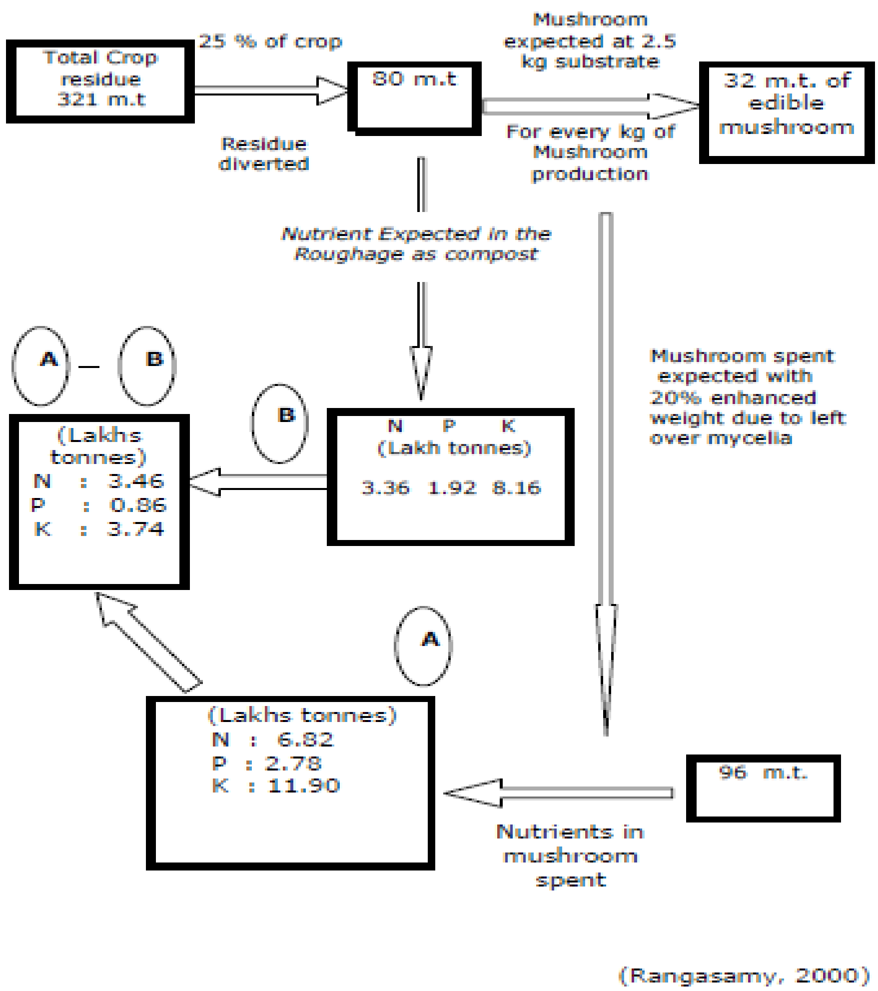
Contingency crop planning and management under such situations include alternate crops or varieties, moisture conservation reduction of plant water stress, mulching and other midterm corrections.

Fig. 1. Projected animal voids and recycling for biogas production with its nutrients in India

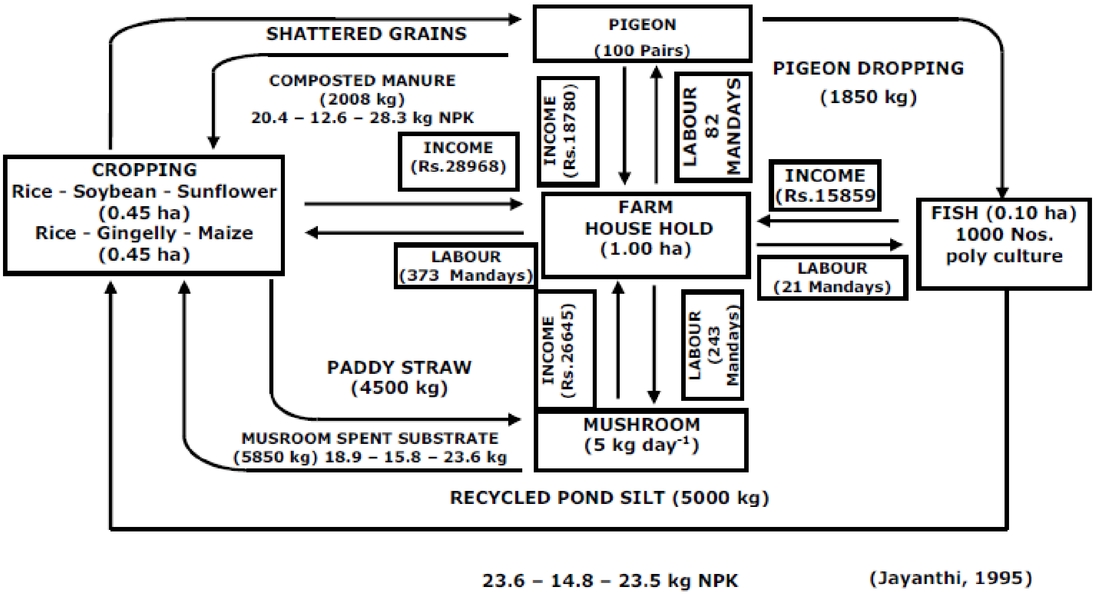


(Rangasamy, 2000)

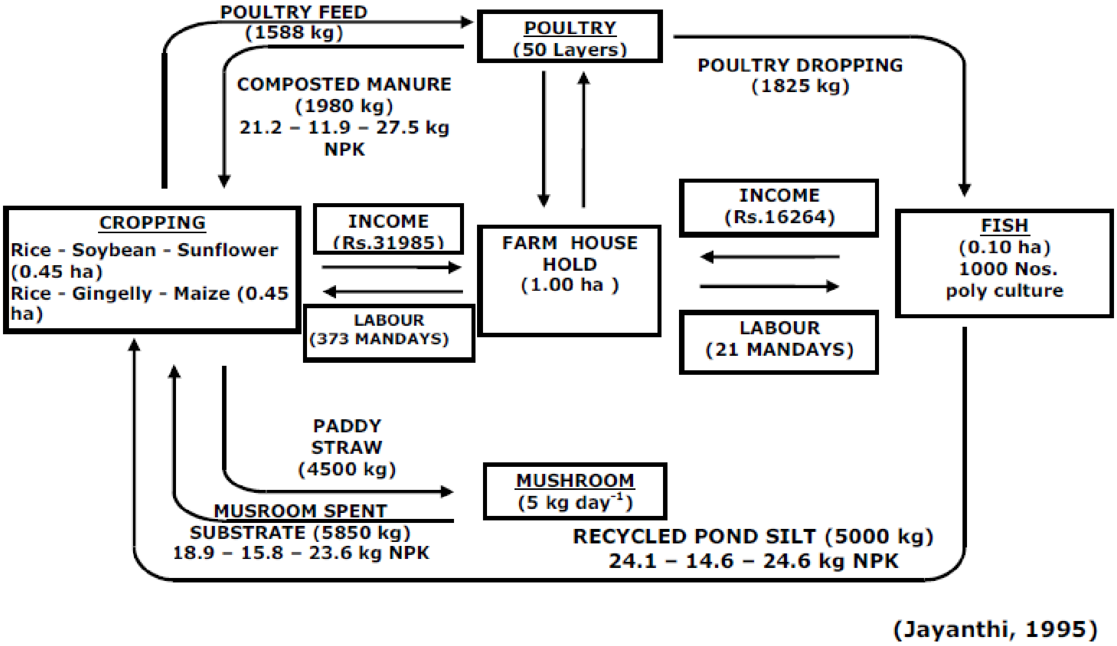
Fig. 2. Projected crop residue and recycling for mushroom production with its nutrients in India



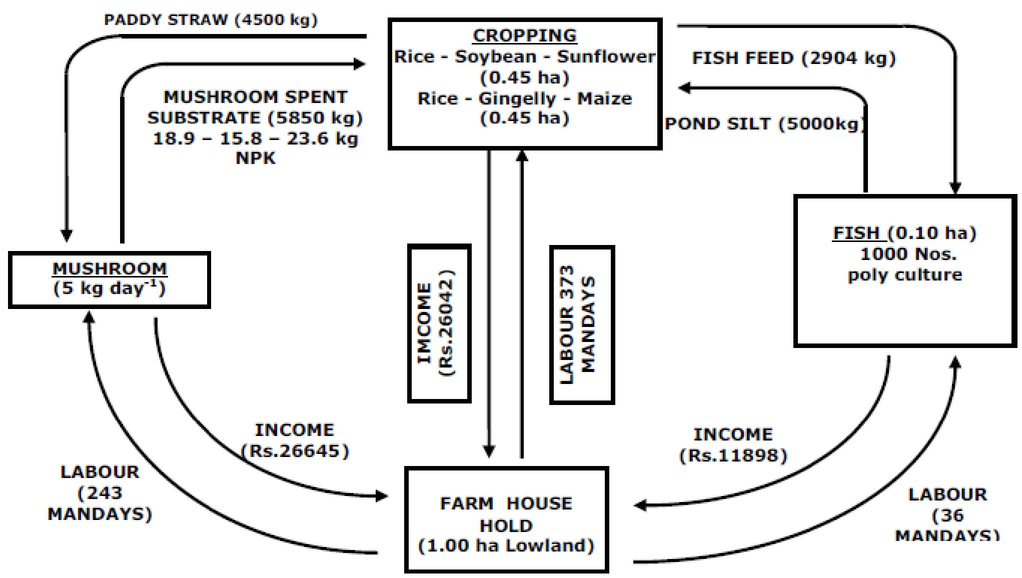
Model 1. Resource Recycling in Crop + Pigeon + Fish + Mushroom Farming



Model 2. Resource Recycling in Crop + Poultry + Fish + Mushroom Farming System



Model 3. Resource Recycling in Crop + Fish + Mushroom Farming System



(Jayanthi, 1995)

Economics of Integrated Farming Systems – Garden lands

Cropping (0.90 ha)
Gross income : Rs.19,488
Expenditure : Rs.10,496
Net income : Rs. 8,992
Contribution to total income : 26%
Employment (mandays / year) : 688

Fodder tree (Silviculture) : Subabul: 200 trees
Gross income : Rs.5992
Expenditure : Rs.3230
Net income : Rs.2762
Contribution to total income : 8%
Employment (mandays / year) : 15

Mushroom spawn Production 30 bottles / day
Gross income : Rs.10493
Expenditure : Rs. 5,651
Net income : Rs. 4842
Contribution to total income : 14%
Employment (mandays/year) : 182

System	Gross income Rs/ha	Expenditure Rs/ha	Net income Rs/ha	Employment (mandays/yr)
Integrated Farming System	74948	40369	34579	1250
Crop cultivation	32220	18343	13877	630
Additional benefit	42728	22026	20702	620

Grain & waste

Manure

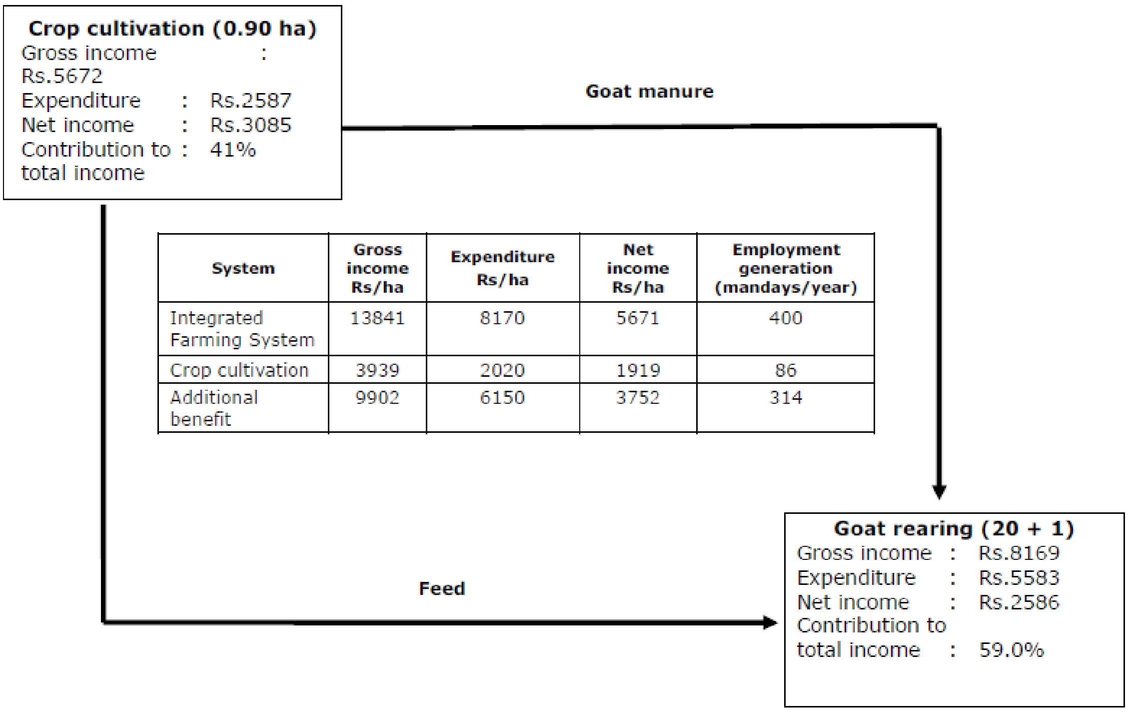
Dairy (Jersey 3 cows + 2 calves
Gross income : Rs.33728
Expenditure : Rs.18166
Net income : Rs.15562
Contribution to total income : 45%
Employment (mandays / year) : 274

Dung

Biogas (capacity 2m^3)
Gross income : Rs.24216
Expenditure : Rs.5247
Net income : Rs.2826
Contribution t o total income : 7.0%
Employment (mandays / year) : 91

(Rangasamy, 1995)

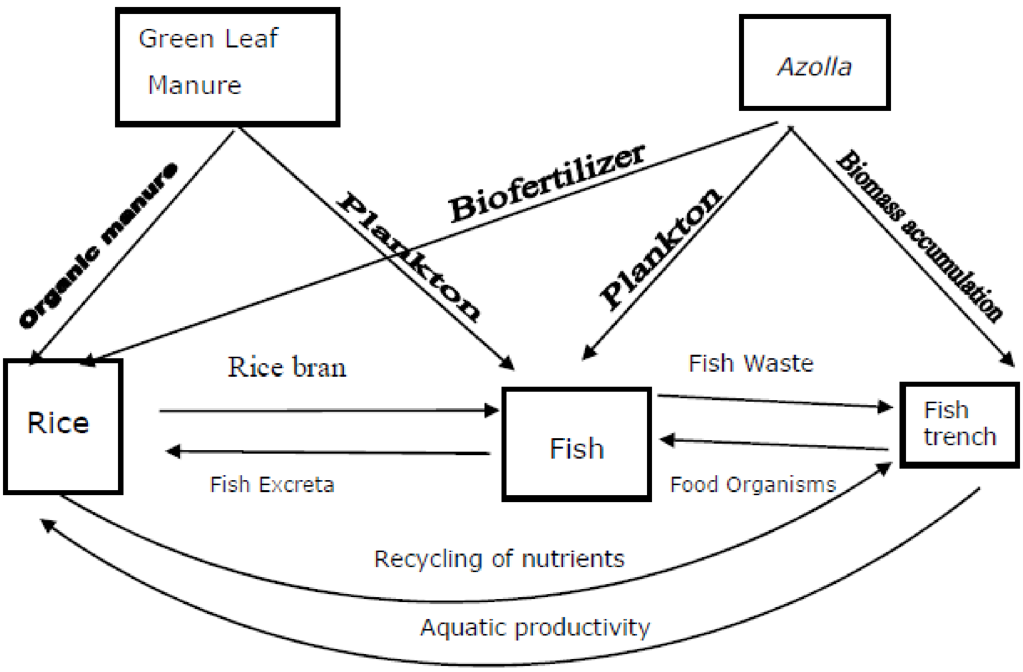
Economics of Integrated Farming Systems – Dry Lands



System	Gross income Rs/ha	Expenditure Rs/ha	Net income Rs/ha	Employment generation (mandays/year)
Integrated Farming System	13841	8170	5671	400
Crop cultivation	3939	2020	1919	86
Additional benefit	9902	6150	3752	314

(Rangasamy, 1995)

Fig 3. Bio resource flow in Rice-Fish –Azolla integrated farming system



Lecture. 13. Integrated Farming System evaluation indicators

Evaluation of Farming System

Productivity

Production per unit area. To estimate the productivity of a component and compares with the crop component expressed in terms of equivalent crop yield. Further the production estimation itself varies among the interlinked animal component in Integrated Farming System.

Eg. Rice based farming systems

Productivity in-terms of grain yield was recorded and expressed as kg of rice grain equivalent yield (GEY), calculated as

$$\text{GEY} = \frac{\text{Productivity of component /intercrop(kg)} \times \text{cost of the component /intercrop (Rs/kg)}}{\text{Cost of main crop (Rs/kg)}}$$

Economic analysis

Parameters like cost of cultivation, cost of production, gross and net returns and per day return were worked out and expressed as Rs. ha^{-1}

Employment generation

- Labour required for various activities in crop production given as man days /ha/year
- A man working for 8 hours in a day is considered as one man day.
- A woman working for the same period is treated as 2/3 man days and computed to man days

Productivity of Livestock components

Fisheries :

Fish weight recorded at harvest and expressed as kg / unit area.

Poultry

Egg production per day from birds and expressed as total number per month or month from the unit.

Pigeon

Growth rate at monthly interval and weight at the time disposal recorded and expressed as kg/unit

Mushroom

Yield per day and total yield per year from the unit

Water requirement

Water requirement for varying component linkage in the integrated farming systems expressed in ha cm.

Residue addition

The quantity of residue available form each component (kg)

Potential residue additions in terms of N, P and K

Energy efficiency

Energy input and output were worked out for individual components based on the input and output energies and energy efficiency suggested by Mittal et al., (1985) and Gopalan et al., (1976)

Nutritive value

Nutritive values in terms of carbohydrate, protein and fat (kg)

Cropping Sequences	Cycle
Sugarcane (planted) - Sugarcane (ratoon) - banana	3 years
Banana - Turmeric - Rice - Banana	3 years
Maize - Rice - Sesame - Sunnhemp	Annual
Fodder component	
Bajra - Napier + Desmanthus (3:1)	Perennial
Fish component	
Pond size : 0.4 ha and depth of 1.5 m	Annual
400 poly culture fingerlings (Catla, Rogu, Mirgal/Common carp and Grass carp @ 40:20:30:10)	

(Jayanthi, 2001)

CASE STUDY
METHODOLOGY

Enterprises	Area (ha)
Crop activity	0.75
Fodder to feed goat unit	0.10
Goat shed	0.03
Fish ponds (3 Nos)	0.12

Integrated Farming Systems

- Crop + Fish +Poultry (20 Bapkok layers)
- Crop + Fish + Pigeon (40 Pairs)
- Crop + Fish + Goat (20 + 1, Tellicherry breed in deep litter system)

System Productivity (Rice grain equivalent) of Integrated Farming System

Farming systems	Component productivity (kg)*					System productivity (kg/ha)	% over CCS
	Crop	Poultry	Pigeon	Fish	Goat		
Crop	12995	-	-	-	-	12995	-
Crop + Fish + Poultry	26352	1205	-	2052	-	29609	128
Crop + Fish + Pigeon	24854	-	2545	1774	-	29173	124
Crop + Fish +Goat	25725	-	-	1975	9979	37679	190

* Mean over three years

Economic analysis of Integrated Farming System

Farming Systems	Production Cost (Rs/ha)	Gross Returns (Rs/ha)	Net Return (Rs/ha)	B:C Ratio	Per day Return (Rs.)
Cropping Alone	27822	64975	37153	2.43	178
Cropping + Fish + Poultry	4833	146035	97731	3.02	400
Cropping + Fish + Pigeon	47090	145868	98778	3.06	400
Cropping + Fish + Goat	55549	186667	131118	3.36	511

Employment Generation in IFS

Farming systems	Employment generation (man days)					
	Crop	Poultry	Pigeon	Fish	Goat	Total
Cropping alone	369	-	-	-	-	369
Crop + Fish + Poultry	420	61	-	34	-	515
Crop + Fish + Pigeon	420	-	61	34	-	515
Crop + Fish + Goat	420	-	-	34	122	576

Nutrient Value of Recycled Manures

Particulars	Poultry	Pigeon	Goat
Birds /animals used to satisfy the feed requirement of 400 fingerlings	20 layers	40 pairs	3 animals
Quantum of dropping received in an year	700 kg	700 kg	810 kg
Silt cleared after one year from 0.04 ha Pond	4.5 t	4.5 t	4.5 t

Nutrient	Raw poultry dropping		Pond manure		Additional nutrient gained (kg)
	%	kg/ 700kg	%	kg/ 4500 kg	
N	3.22	22.5	1.96	88.2	65.7
P2O5	2.50	17.5	1.02	45.9	28.4
K2O	1.05	7.4	0.72	32.4	25.0

Nutrient	Raw pigeon dropping		Pond manure		Additional nutrient gained (kg)
	%	kg/ 700kg	%	kg/ 4500 kg	
N	1.82	12.7	0.84	37.8	25.1
P2O5	0.56	3.9	0.30	13.5	9.6
K2O	0.98	6.9	0.56	25.2	18.3

Nutrient	Raw Goat dropping		Pond manure		Additional nutrient gained (kg) %
	%	kg/ 810kg	%	kg/ 4500 kg	
N	1.40	11.3	0.70	N	1.40
P2O5	0.85	6.9	0.62	P2O5	0.85
K2O	0.70	5.7	0.48	K2O	0.70

Residue Recycling in Integrated Farming systems

Farming System	Residue addition (kg)						Nutrient addition (kg)		
	Crop	Poultry	Pigeon	Fish	Mushroom	Total	N	P	K
Cropping Alone	4702	-	-	-	-	4702	34.5	8.3	50.9
Crop+ Poultry+ Fish+ Mushroom	3689	1980	-	5000	5850	16519	241.2	145.9	246.4
Crop+ Pigeon+ Fish+ Mushroom	3455	-	2008	5000	5850	16313	235.6	147.5	234.8
Crop+ Fish+ Mushroom	3317	-	-	5000	5850	14167	189.3	157.8	235.8

Water Requirement (ha cm) of Integrated Farming System

Farming System	Component water requirement (ha cm)					System requirement (ha cm)
	Crop	Poultry	Pigeon	Fish	Mushroom	
Cropping Alone	182	-	-	-	-	182.00 (60.2)
Crop+ Poultry+ Fish+ Mushroom	201	0.02	-	15.84	1.37	218.23 (145.1)
Crop+ Pigeon+ Fish+ Mushroom	201	-	0.04	15.84	1.37	218.25 (154.1)
Crop+ Fish+ Mushroom	201	-	-	15.84	1.37	218.21 (123.1)

Figures in parenthesis indicate rice grain equivalent yield (kg ha cm^{-1})

Nutritive value of components in integrated farming systems : Carbohydrate yield (kg ha^{-1})

Farming System	Component contribution (kg)			System Total (kg ha^{-1})
	Crop	Fish	Mushroom	
Cropping alone	8182	-	-	8182
Crop+ Poultry+ Fish+ Mushroom	6438	24	72	6534
Crop+ Pigeon+ Fish+ Mushroom	5926	23	72	6021
Crop+ Fish+ Mushroom	5693	25	72	5790

Nutritive value of components in integrated farming systems : Protein yield (kg ha^{-1})

Farming System	Component contribution (kg)					System Total (kg ha^{-1})
	Crop	Poultry	Pigeon	Fish	Mushroom	
Cropping Alone	1292	-	-	-	-	-
Crop+ Poultry+ Fish+ Mushroom	1486	87	-	106	272	106
Crop+ Pigeon+ Fish+ Mushroom	1395	-	192	104	272	104
Crop+ Fish+ Mushroom	1313	-	-	110	272	110

Nutritive value of components in integrated farming systems : Fat yield (kg ha^{-1})

Farming System	Component contribution (kg)					System Total (kg ha^{-1})
	Crop	Poultry	Pigeon	Fish	Mushroom	
Cropping Alone	567	-	-	-	-	567
Crop+ Poultry+ Fish+ Mushroom	1251	83	-	8	13	1355
Crop+ Pigeon+ Fish+ Mushroom	1163	-	40	7	13	1223
Crop+ Fish+ Mushroom	1097	-	-	8	13	1118

Energy value (K Cal) of integrated farming systems :

Farming System	Component contribution (K Cal)					System Total (K Cal)
	Crop	Poultry	Pigeon	Fish	Mushroom	
Cropping Alone	4301716	-	-	-	-	4301716 (11786)
Crop+ Poultry+ Fish+ Mushroom	4047960	1075576	-	530264	714419	6368219 (17447)
Crop+ Pigeon+ Fish+ Mushroom	3754626	-	1124770	519868	714419	6113683 (16750)
Crop+ Fish+ Mushroom	3576285	-	-	554649	714419	4845353 (13275)

(Figures in parenthesis indicate per day energy availability)

Farming Systems Research

Farming Systems Research method is designed to understand farmer's priorities, strategies and resource allocation decisions. It is most often used in conjunction with On-Farm Research to identify and adopt technologies useful to location specific problems of farmers.

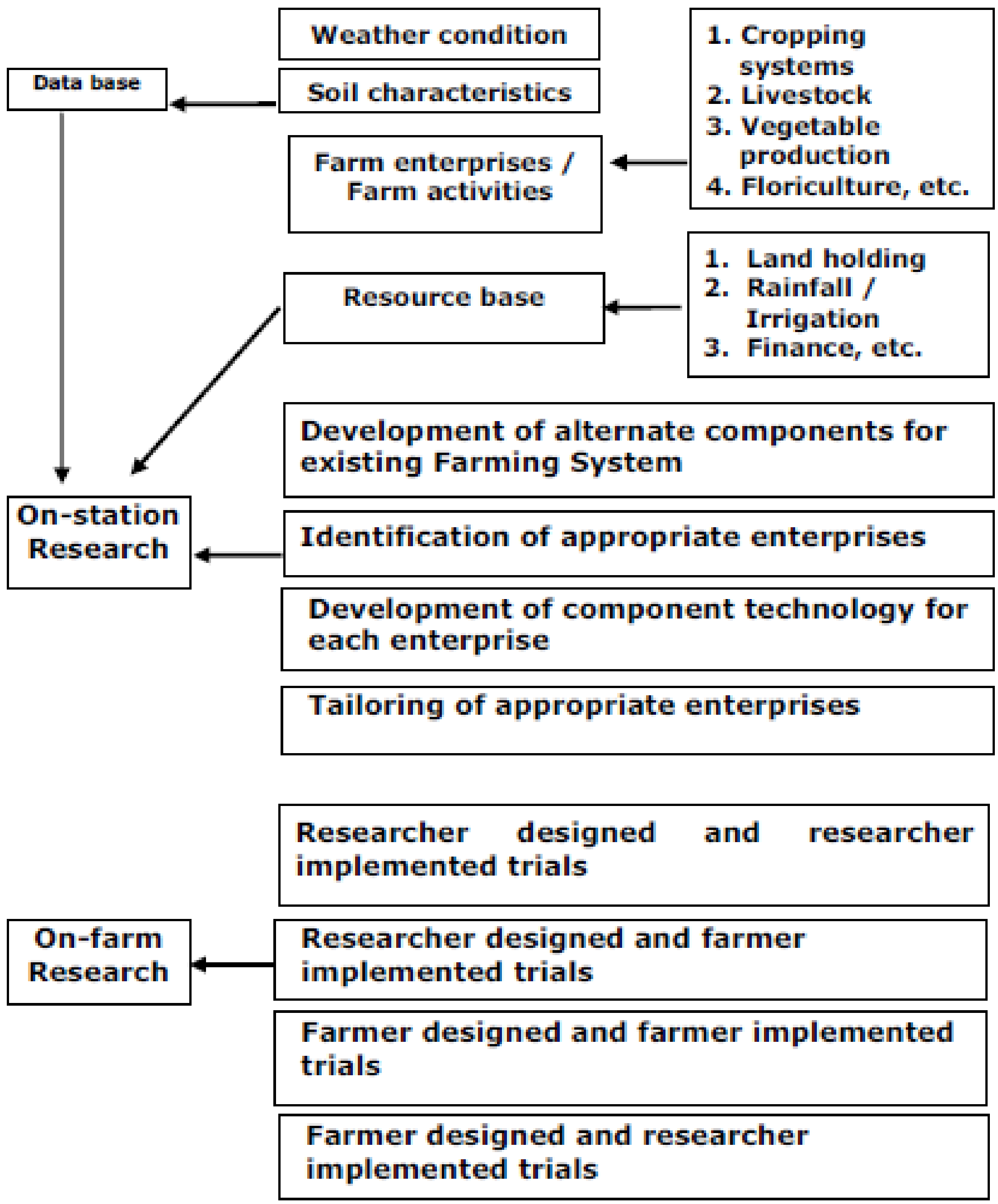
Goals of farming systems research

- Maximization of yield of all components to provide steady and stable income at higher levels
- Optimizing resource use
- Minimizing degradation considering regenerative capacity
- Enhancing employment
- Promoting quality life and environment

Objectives of Farming System Research

- Identifying constraints to increase farm productivity
- Providing technological interventions at given resource level
- Refining technologies through farmer participatory research
- Monitoring the impact of system related technologies in satisfying needs of growing population

Frame work of Farming Systems Research



Priorities of FSR

- Prioritizing research problems and production constraints
- Prioritizing the interaction for farmer preferences and identifying risks/problems with each intervention
- Research design and technology generation and adaptation
- Testing and monitoring of designed intervention
- Technology transfer and diffusion of improved farming system with recommendation domain
- Impact of technology of improved farming system
- Integration of CSR and extension
- Developing multi-disciplinary terms for OFR

Stages in farming system research

- Diagnostic stage
- Experimental stage
- Testing stage
- Extension cum monitoring stage

Activities involved in each stages of farming system research

- Base data analysis
  Collection, collation and analysis of data characterizing environment and farming systems of given region
- Research station studies
  Aiming at development of components and evaluation of system
- On-farm studies
  Assessment of the impact of new technology in relation to the farm household

Farming System Research – Focus

- Farmer-oriented
- System-oriented
- Problem-solving approach
- Interdisciplinary
- Complements mainstream disciplinary research
- Tests technology in on-farm trials
- Provides feedback from farmers.

Impact studies of FSR

- Production efficiency
- Economic returns
- Energy input/output
- Employment
- Equity
- Environment

Lecture 14. Integrated farming system - models for wetland, irrigated upland and dryland eco system

Models of Integrated Farming System for Wet, Garden and Drylands

Factors influencing the selection and size of components in Farming Systems

- Climatic conditions - Rainfall, temperature, solar radiation, wind, humidity, etc.
- Soil type
- Farmers preferences
- Size of the Farm
- Knowledge, skill and technology
- Storage, transport and marketing
- Resource mobilizing power of the farmer
- Credit facilities available
- Socio-economic condition
- Customs, sentiments and believes

Steps involved in the preparation of a model Integrated Farming System to a specific situation

1. Assessment of available resources
2. Identifying the existing cropping system
3. Identifying component(s) to be integrated
4. Fixing the size of the individual components
5. Working out the requirement of the components
6. Modifying the existing cropping system to suit the requirements of the components integrated
7. Working out the economics of individual components and for the IF system as a whole
8. Identifying constraint and suggesting remedy measures/modifications for technical feasibility, economic viability and practical utility.

Cropping in low land (Wetland) is considered to be less risky due to abundant availability of water. In addition, most of the low land soils are heavy type of soils, which are fairly fertile soil. Mostly rice is the principle crop in our low lands. Crops like Banana, Sugarcane and Coconut are also grown in this ecosystem. Diversified farming (IFS) can be adopted in the low lands with the components like Fish, Poultry, Duck and Mushroom. The possible IFS that can be practised using these components are

Example:

a) Rice + Fish + Azolla

b) Rice + Fish + Poultry / Duck

c) Rice + Fish + Poultry - Mushroom

Wetland Integrated Farming System

Eg. 1. Cropping + poultry/pigeon + fish culture + mushroom - 0.40 ha

Farming system components				**Area (ha)**
I. Cropping				
Sep-Oct	**Feb-Mar**	**Jun-Jul**		
Rice	- soybean	- sunflower	:	0.18
Rice	- gingelly	- maize	:	0.18
II. Fish - 400 polyculture fingerlings			:	0.04
III. Pigeon			:	40 pairs
IV. Poultry	- over the fish pond		:	20 Nos.
V. Mushroom	- 2kg production capacity			

Productivity, economics and employment generation

Farming Systems	**System productivity (kg ha^{-1})**	**Net return (Rs. ha^{-1})**	**Employment generation (mandays ha^{-1})**
Cropping alone	10959	26725	364
Crop + Poultry + fish + Mushroom	31660	79927	798
Crop + Pigeon + fish + Mushroom	33768	90393	719
Crop + fish + Mushroom	26865	64585	637

(Jayanthi, 1992-1995)

Irrigated upland

The possibility of having a viable integrated farming system in irrigated uplands is possible. The control and management of available resources in more effective manner paves way to integrate two are more components with cropping. The choice of components is many in irrigated upland compared to lowlands and rainfed lands. Components like Dairy, Poultry, Goat, Sheep, Piggery, Sericulture, Mushroom, Apiary, Pigeon, Rabbit, Quil, etc. can be easily integrated in a n irrigated upland farm. In addition perennial trees like coconut and other fodder and multipurpose farm forestry trees can be grown along the borders of the fields and boundary of the farm.

Special Features of Irrigated Upland

1. Wide range of crops and varieties can be grown
2. Effective resource utilization and management is possible due to controlled irrigation system

The following are some of the examples of Integrated Farming System for irrigated uplands

1. Crop + Dairy + Biogas unit
2. Crop + Poultry + Biogas unit
3. Crop + Sheep / Goat rearing + Biogas unit
4. Crop + Sericulture
5. Crop + Piggery
6. Crop + Sericulture + Biogas unit
7. Crop + Dairy + Biogas unit + Homestead garden
8. Crop + Dairy + Biogas unit + Vermicompost

IFS model under irrigated upland situation

Eg. Cropping + dairy+ biogas + mushroom + fish

Farming system components		Area (ha)
CCS - Conventional cropping systems with crop alone	:	1.00
FS_1 - IFS with crop + dairy	:	1.00
FS_2 - IFS with crop + dairy + biogas	:	1.00
FS_3 - IFS with crop + dairy + biogas + mushroom	:	1.00
FS_4 - IFS with crop + fish (artificial feeding)	:	1.00
FS_5 - IFS with crop + fish (Biogas slurry) + dairy + biogas	:	1.00
FS_6- - IFS with crop + fish (Cattle shed washing) + dairy	:	1.00

I. Cropping

Conventional cropping systems (CCS)

June-August	September		Area (ha)
i) Sorghum	Cotton	:	0.50
ii) Maize	Cotton	:	0.50

Cropping systems in Integrated Farming System

June-August	September		Area (ha)
i) Sorghum + Redgram	Sunflower + coriander	:	0.32
ii) Maize + Fodder cowpea	Cotton + coriander	:	0.32
iii)Perennial fodder (CO3 grass) + legume fodder (Lucerne)		:	0.32

II. Dairy - 6 jersey cows and 4 calves
III. Biogas unit - 2 m^3
IV. Fish - 80 m^2 - 80 fingerlings
} : 0.04

Productivity, economics, residue addition and employment generation of the system

Farming systems	System productivity (kg ha^{-1})	Net return (Rs. ha^{-1})	Employment generation (man days)	Residue addition (kg ha^{-1})
CCS	11091	35021	394	2250
FS_1	33923	117850	692	5800
FS_2	34891	126839	704	6046
FS_3	45980	168530	875	7989
FS_4	12068	40722	414	7476
FS_5	34495	125267	705	9337
FS_6	33271	115958	695	9527

(Sivamurugan, 1998-2001)

Dryland ecosystem

The dryland ecosystem of Tamil Nadu is characterized by

1. Inadequate and uneven distribution of rainfall
2. Poor and marginal soils
3. Low cropping intensity
4. Limited crop diversification
5. Low value crops
6. Poor resource mobilizing power of farmers

The agriculture in drylands is seasonal. The cropping season is restricted to 4-5 months and people remain without employment for rest of the year. Diversification of cropping by integrating with components like livestock (Sheep/Goat rearing), silviculture, horticulture tree crops and pastures would improve the standard of living and employment opportunities of the dryland farmers.

Integrated farming system is a boon to dry land farmers. When compatible components/ allied activities/ associated enterprises are suitably combined, farming in drylands becomes less risky and remunerative. IFS on a watershed approach are the best way of alternative agriculture in dryland areas. The following components are identified as appropriate to dryland situations.
Goat / Sheep rearing, Silviculture, Agroforestry, Farm Forestry, Horticultural tree crops

Possible combinations are

Crop + Silvipasture + Goat / Sheep rearing

Crop + Silviculture + Hort. Fruit trees

Crop + agro-forestry + goat + farm pond

Crop + Silvipasture + Goat + pigeon + farm pond

Crop + Silvipasture + Buffalo + farm pond

IFS model under Dryland situation

Eg. Cropping + pigeon + goat + buffalo+ agroforestry + farm pond + border planting - 4.0ha

Farming system components		Area (ha)
CCS - Conventional cropping system with crop alone	:	1.0
FS_1 -IFS with crop + pigeon + goat + agroforestry + farm pond	:	1.0
FS_2 -IFS with crop + pigeon + buffalo+ agroforestry + farm pond	:	1.0
FS_3 -IFS with crop + pigeon + goat + buffalo + agroforestry + farm pond	:	1.0
Border planting of *Glyricidia sepium* along field boundaries		
I. Cropping		
Conventional cropping		
Sole sorghum (CO 26) with recommended practices	:	1.0
Cropping system in IFS		
i) Maize (F) + Cowpea (F) - Chickpea + Coriander	:	0.25
ii) Sorghum (F) + Cowpea (F) - Chickpea + Coriander	:	0.25
iii) Sorghum (G) + Cowpea (G)	:	0.20
iv) Sunflower + Coriander	:	0.10
II. Agroforestry		0.10
(*Acacia nilotica* + *Cenchrus ciliaris*)		
(Sorghum (F) + Cowpea (F))		
III. Buffalo (2 milking & 1 calf) and (or) Goat (5+1 female: male)		0.05
IV. Pigeon (10 pairs)		0.01
V. Farm pond		0.04

Productivity, Economics, Residue addition and Employment generation of the system

Farming systems	System productivity (kg ha^{-1})	Net return (Rs. ha^{-1})	Employment generation (man days)	Residue addition (kg ha^{-1})
CCS	1270	1,167	30	1,688
FS_2	4723	9,304	113	3,855
FS_3	10994	22,670	141	10,383
FS_4	12387	21,818	163	11,583

(Esther shekinah, 1998-2002)

Advantages of IFS under dryland

1. Risk is minimized
2. Optimum use of resources
3. Soil and moisture conservation will be improved
4. Income is stabilized during period of drought

Lecture 15. LEIA and HEIA - principles and concepts and Labour management in integrated farming system

Low External Input Agriculture (LEIA)

The term low-input agriculture has been defined as a production activity that uses synthetic fertilizers or pesticides below rates commonly recommended by the Extension Service. It does not mean elimination of these materials. Yields are maintained through greater emphasis on cultural practices. IPM, and utilization of on-farm resources and management.

High External Input Agriculture (HEIA)

In view of the limited access of most farmers to artificial external inputs, the limited value of these inputs under LEIA conditions, the ecological and social threats of 'green revolution' technology and the dangers of basing production on nonrenewable energy sources, the strong emphasis on High External input Agriculture (HEIA) in agricultural development must be questioned. However, it is also open to question whether it will be possible to raise world food production sufficiently without the use of such external inputs. Besides, natural; as opposed to artificial inputs can, also have detrimental environmental effects.

Low External Input Supply Agriculture (LEISA)

LEISA is an option which is feasible for a large number of farmers and, which can complement other forms of agricultural production. As most fanners are not in a position to use artificial inputs or can use them only in small quantities, it is necessary to concentrate on technologies that make efficient use of local resources. Also, those farmers who now practice HEIA could reduce contamination and costs and increase the efficiency of the external inputs by applying some LEISA techniques. It is important that the agro-ecological knowledge of both scientists and farmers be applied, so that internal and external inputs can be combined in such a way that the natural resources are conserved and enhanced, productivity and security are increased and negative environmental effects are avoided.

The process of combining local farmers' knowledge and skills with those of external agents to develop site-specific and socio-economically adapted farming techniques has been given the name '*Participatory Technology Development'* (PTD). Farmers work together with professionals from outside their community (e.g., extension workers, researchers etc.), in identifying generating, testing and applying new techniques. OTD seeks to strengthen the existing experimental capacity of farmers and to encourage continuation of the innovation process under local control. The experience of combining indigenous and scientific knowledge through a process of PTD indicates strongly that it is indeed possible to transform LEIA to LEISA: Low External-Input and Sustainable agriculture. This approach to agricultural development appears to be better adapted to the needs and opportunities of LEIA farmers and to fit better into their cultural context than the conventional approach.

The LEISA concept seeks to optimize the use of locally available resources by maximizing the complementary and synergistic effects of different components of the farming systems. External inputs are used in a complementary way.

Although, the term low-input farming often been used to describe any system of alternative agriculture, if can be seen that it is distinctly different from organic farming etc. Nevertheless, any system that reduces purchased chemical inputs can be called low-input farming, some examples are:

1. FYM/Poultry litter can replace nitrogen fertilizers in the production crops
2. Legume cover crops can supply the total nitrogen requirements of associated non-legumes.
3. Compost amended potting mixes produce superior vegetables than traditional soilless mixes.
4. No-till vegetable systems lire feasible using reduced herbicide rates to kill cover crops.
5. Subterranean clover living mulches supply nitrogen and weed control in peach orchards.

Integrated pest management is probably the oldest and most widely recognized Extension Service program devoted to low-input agriculture. However, only recently have the non-chemical approaches-such as cultural, mechanical, and biological-within the IPM framework been emphasized over the chemical component. Some programs, in fact, are now termed biologically-intensive IPM.

The intentions of the LEISA concept are obvious, but in practice the way it differs from integrated agriculture (understood to be a gradual minimization of external inputs) is not too clear. Defining what constitutes low inputs will always be difficult; therefore, LEISA remains an ambiguous concept.

Important characteristics of LEISA systems are that they are based on a preventive approach whereby the problem is tackled at its roots, as opposed to the more symptom-curing nature of modern agriculture. Ecological and biological principles are the basis of the farm system. Nature works for the farmer, the farmer does not have to work against it. They are often based on local knowledge and production systems adapted to modern requirements and much less on external expertise. They are generally more labor-intensive compared to the mechanization-and petrochemical-intensive character of the agriculture envisioned by the Green Revolution and what it has become.

Basic concepts of LEISA

- LEISA refers to those forms of agriculture that seek to optimize the use of locally available resources by combining the different components of the farm system i.e., plants, animals, soil water, climate and people, so that they complement each other and gave the greatest possible synergistic effects.
- Seeks way of using external inputs only to the extent that they are needed to provide elements that are in deficient in the eco system and to enhance available biological, physiological, physical and human resource. In using external inputs, attention is given mainly to maximum recycling and minimum detrimental impact on the environment.
- LEISA aims at a stable and adequate production level over the long term. LEISA seeks to maintain, and where, enhance the natural resources and make maximum use of natural process. Where part of the production is marketed, opportunities are sought to regain the nutrients brought to the market.
- LEISA requires management not only at farm level but also at district, regional, national and even international level.
- LEISA incorporates that best components of indigenous farmers knowledge and practices, ecologically – sound agricultural practices developed elsewhere, commercial science and new approaches in science (eg., Systems approach, agro-ecology, biotechnology).
- LEISA practices must be developed within each ecological and socio economic systems. The specific strategies and techniques will vary accordingly and will be in numerable.

Ecological principles

The insights and experience gained thus in agro ecological studies, indigenous agriculture in the tropics and ecological farming throughout the world point to some basic ecological principles which can guide the process of developing LESIA systems. The ecological principles basic to LEISA can be grouped as follows.

1. Securing favourable soil conditions for plant growth particularly by managing organic matter and enhancing soil life.
2. Optimize nutrient availability and balancing nutrient flow, particularly by means of nitrogen fixation, pumping, recycling and complementary use of external fertilizers.
3. Minimizing losses due to solar radiation, air and water by way of microclimate management, water management and erosion control.
4. Minimizin`g losses due to plant and animal pests and disease by means of premonitory and safe treatment.
5. Exploiting complementary and synergy in the use of genetic resources, which involves combining these integrated farm systems with high degree of functional delivery.

Criteria for LEISA

Ecological Criteria

1. Balanced use of nutrients and organic matter
2. Efficient use of water resources
3. Diversity of genetic resources
4. Efficient of genetic resources
5. Efficient use of energy sources
6. Minimal negative environmental effects
7. Minimal use of external inputs

Economic Criteria

1. Sustained farmer livelihood systems
2. Competitiveness
3. Efficient use of production factors
4. Low relative value of external inputs

Social Criteria

1. Wide-spread and equitable adoption potential, especially among small fanners
2. Reduced dependency on external institutions
3. Enhanced food security at the family and national level
4. Respecting and building on indigenous knowledge, beliefs and value systems
5. Contribution to employment generation

Labour management under high labour cost, scarcity and peak season demand for labour

- In crop production, land labour and capital are three important resources to be managed efficiently. However, mgt of labour is a difficult process.
- Whenever any programme is drawn the role of labour should also be considered.
- The share of labour in most costs of cultivation of crops is 50-60%.
- Energy requirement for various operations and the human labour energy utilization is also considerably high.
- Cost of human energy when compared to total is to be given due attention

Crop	% of human energy to total energy
Cotton	22.15 %
Bajra	17.65 %
Maize	16.29 %
Ragi	27.76 %
Sorghum	13.10 %

Efficient labour management is essential, but yet it is very difficult because labour as a resource has certain unique features which are not seen in other resources. They are

a. Services of labour can not be stored. As and when available it is to be used. Otherwise it is wasted.
b. Labour comes in indivisible unit.
c. In small farms family labour constitutes a considerable share.
d. Management of human labour requires specific skill involving human psychology

Problem in management of human labour

1. Labour inefficiency: More labourers required and delayed operations.
2. Frequent increases in wages - not in accordance by the price of produces
3. Labour strike as a result of labour organisation.
4. Demand for wage hike during critical work periods.
5. Shortage of labour during peak requirement period i.e. there will be labour shortage in one part of the year, as agricultural is highly seasonal
6. Heterogeneous group –leads poor efficiency & quality is also affected.

Measurement of labour efficiency

1. Labour cost/unit area.
2. Number of labourers/unit area.
3. Labour output/unit time.
4. Productivity of crop/ man-day or man-hour.

Methods of efficient labour management is possible by

1. Increasing the labour productivity.
2. Reducing the labour requirement.
3. Reducing the labour cost per unit area.
4. Overcoming difficulties arising out of labour shortage during peak period
5. Better personnel management.

Increasing the labour productivity

a. By proper selection of labourers- with good physique, necessary skill and enough experience in various farm operations.
b. By prompt payment of optimum wages (Timeliness & appropriate).
c. By carrying out the operations under optimum field conditions Eg. Weeding at optimum stage and moisture.

d. Right choice of tools for manual operations. Weeding with hand hoe or dryland weeder.

1. Reducing the labour requirement

a. *Using labour saving implements*

Eg. Forming ridges and furrows by Ridger. It reduces 70-80 % labour requirement. By using 5 tyned seed drill for sowing bold seeds 45% of labour can be saved. For green fodder cutting with power operated chaff cutters, 2 men can chop 5 t of green fodder and 2 t of dry fodder.

b. *Using herbicides for weed control*

For most crops, use of herbicides, reduce the labour requirement.

Eg. For hybrid maize – Pre-emergence use of atrazine + one late intercultivation reduced the labour requirement.

c. *By mechanisation*

Eg. Tractor for preparatory cultivation. Paddy thrasher – very quick with 5 man-days while 26 man-days are required if done mannually.

d. *By changing the method of crop establishment*

Eg. By direct seeding, instead of nursery and transplanting, rice throwing seedling thereby the labour requirement can be reduced.

2. Reducing the labour demand during peak period

a. Allow willing labourers to do extra time work and pay extra wages.

b. Use of uncertain seasonal labour force. Eg. Engaging non-agri people for flower picking, stripping/ shelling groundnut pods, collection of caterpillars in cotton by school children.

c. Adopt contract system of work. Payments are made on quantity of work turned out and here again the problem is quality of work.

d. By changing the cropping pattern the sequence of crop should allow long distribution of labourers, without peaks and slacks. There are certain crops for which season is not so rigid eg. Sunflower – a day neutral plant.

e. Drawing of calendar of labour requirement and labour availability.

f. Carrying out the less important operations during slack period.

Eg. Paddy harvest - winnowing and cleaning of dried paddy and staking of paddy straw can be delayed.

3. Tips for efficient labour management

1. Motivate the labourers by appreciation.
2. Clear communication with crystal clear instructions.
3. Try to fulfill their physical needs like shelter, food and clothing.
4. Provide safety and security with better care and affection.
5. Protect the self-esteem of the labourers and also the achievement.

" Listen to labourer ''

Measurement of labour efficiency

1. Labour cost / unit area
2. Number of labours / unit area
3. Labour output / unit time
4. Productivity of crop / man day or man hour

1. Labour cost / unit area

1It varies from crop to crop. If normal cost for a crop isRs.1000/-, if it is Rs.850/- then there is labour efficiency. If it is Rs.1000 then there is labour inefficiency.

2. No. of labours / unit area

If for a crop, it is 200 man days normal. If it is > 200-poor labour efficiency if it is <200, then better labour efficiency. It also varies from crop to crop.

3. Labour output / unit time

It refers to work turned out by a labour in unit time or a day of 8 hours. For each and every operation it is assessed.

4. Productivity / mandays or man hour

- Quantity of produce obtained / unit area
- No. of man days / man hour required. If the value is higher, then is desirable.
- There are certain limitations; this is used to assess the labour efficiency. With the same amount of labour, higher productivity could be obtained with efficient management of other inputs.

Lec 16. CONSERVATION AGRICULTURE

In India, due to increased population, the demand for food production has increased and it has put pressure on land to get more output from the same field. This has resulted in over exploitation of natural resources, resulting in the water table having gone down in some places. In some places, water tables have gone up and the salts have leached above the soil surface. The excess application of chemicals have polluted the ground water and burning of farm residues to clear the fields for sowing in the next crop. This practice has resulted in environmental pollution and CHGs. Such practice has prompted the adoption of CA, a term resulting as an offshoot of CT studies for promoting use of zero till drills and reduced tillage.

Excessive tillage causes the soil to become denser and compacted, increases run off and soil erosion and reduces organic content due to burning of crop residues. It also leads to droughts becoming more severe and soil becoming less fertile and less responsive to fertilizer. To address to these concerns, it was necessary to achieve sustainable production systems when the basic principles of good farming practices are applied. The terminology adopted for such systems by FAO, ECAF and other organizations is CA. Many definitions of CA have been given as a result of many researches. Some of these definitions are stated below.

CA refers to the system of raising crops without tilling the soil while retaining the crop residues on the soil surface. Land preparation through precision land levelling and bed and furrow configuration for sowing crops further enables improved resource management. CA aims to achieve sustainable and profitable agriculture and subsequently, at improved livelihoods of farmers through the application of three CA principles; minimal soil disturbance, permanent soil cover, and crop rotation.

CA aims to conserve, improve and make more efficient use of natural resources by practicing integrated management of available soil, water and biological resources combined with external inputs. It contributes to environmental conservation as well as to enhanced and sustained agricultural production. It can also be referred to as resource efficient/resource effective agriculture

CA can also be defined as a range of soil management practices that minimize effects on composition, structure and natural biodiversity and reduce erosion and degradation. Such practices may include precise land levelling by laser leveller to save water, direct sowing or drilling/no-tillage/reduced tillage/tillage for timely sowing, surface incorporation of crop residues and establishment of annual and perennial crops to add organic matter to the soil and avoid burning of straw, thus, pollution is reduced. This is also enhanced through the use of a straw combine followed by bailer to collect the straw lying in the field. The soil is thus protected from rainfall erosion and water runoff; the soil aggregates, organic matter and fertility level naturally increase; soil compaction is reduced and use of fossil fuels and GHG emissions are also reduced. Further, less contamination of surface water occurs, and water retention and storage is enhanced allowing for recharging of aquifers.

CA can be seen as a new way forward, for conserving resources and enhancing productivity to achieve goals of sustainable agriculture, which demands a strong knowledge base and a combination of institutional and technological innovation. It is being perceived by practioners as a valid tool for sustainable land management. Hence, it is being promoted world over including IGP.

CA allows for the management of soil and water for agricultural production without excessively disturbing them. Presently, CA has assumed importance in view of the widespread degradation of natural resources leading to increased cost of production, unsustainable resource use, environmental pollution and health of ecosystems. Therefore, it is very important that CA practices are adopted in different agro-ecological regions without delay. Governments worldwide started giving incentives to the farmers to practice CA and some even formulated conservation policies. Various conservation tillage practices such as zero tillage, minimum tillage, reduced tillage, ridges and furrow method, broad bed and furrow and raised and sunken beds of different widths have been evaluated in different types of soils to reduce land preparation operations and to save energy.

CA has the potential to emerge as an effective strategy in response to the increasing concerns of serious and widespread natural resources degradation and environmental pollution, which accompanied the adoption and promotion of green revolution technologies since the early 1970s. The key challenge today is to adopt strategies that will address the twin concerns of maintaining and enhancing the integrity of natural resources and improved productivity; while improvement of natural resources takes a lead as it forms the very basis for long-term sustained productivity. CA practices in different agro-ecological regions, identifying the technological, socio-economic policy and institutional constraints, defining agenda for research and development, and identifying institutional mechanisms for promoting the strengthened participation of a range of stakeholders as a means of seeking a way forward.

There should be strong linkages between resource degradation and poverty and that CA must be considered a route to sustainable development. Globally, CA systems are being adopted in over 80 million ha largely in rainfed areas. The countries where the system is being adopted and promoted extensively include US, Brazil, Mexico, New Zealand, Australia, Argentina, Canada, South Asia, China, etc. South Asian countries practice CA technologies in the irrigated Indo-Gangetic plains where rice-wheat cropping system dominates. CA systems have not yet taken roots in other major agro-ecological regions, like rainfed, semi-arid tropics, the arid regions or the mountainous agro-ecosystems in India. While the basic principles, which form the foundation of CA practices, i.e., no-tillage and surface managed residues are well understood, adoption of these practices under varying situations is the key challenge. Issues related to technology needs and inputs management addresses some of these basic issues for transition to CA.

The technological challenges related to development, standardization and adoption of farm machinery for seeding with minimum soil disturbance, developing crop harvesting and management systems with residues maintained on soil surface and developing and continuously improving site specific crop, soil and pest management strategies will optimize benefits from the new system.

Emphasis needs to be given to enhancing livelihood opportunities rather than increasing yields. CA marks an evolutionary change through a process of learning that offers the opportunity and a means to achieving policy goals. CA has to offer a way to address broader livelihood issues. The new institutional arrangements must be based on a good understanding of the features that distinguish the principles and practices of CA from the conventional research and development approach. Institutional mechanisms are required to ensure that CA is seen as a concept beyond agriculture. Institutionalizing the role of research, extension and farmers in such a way that the partnership among these stakeholders might be strengthened right from the beginning of the project, helps build up a sense of enabling ownership among them. CA must aim at broad livelihood strategies and move towards forming conservation villages with appropriate agribusiness strategies to increase employment in areas where it is adopted. However, caution must be taken to avoid blanket adoption of CA just every where. It should be site specific and need-based. CA is now considered a route to sustainable agriculture. Spread of CA, therefore will call for a greatly strengthened research and linked development efforts. CA requires a new way of thinking from all concerned, Along with this “new way of thinking agriculture”, there is already enough technical and agronomic evidence that could positively influence farmers contemplating the adoption of CA principles.

It is estimated that about 2 billion ha. in the world is affected by various forms of land degradation which include water erosion (1.1 billion), wind erosion (0.55 billion), chemical degradation (0.24 billion) and physical soil degradation (0.08 billion). According to latest estimates using global assessment of soil degradation, about 188 m. ha or 57 per cent of land is potentially exposed to various degradation forces, of which water erosion constitutes a major section of 148.9 m. ha or 45 per cent; and the remaining 38.9 m ha or 12 per cent suffer from wind erosion; 13.8 m ha or 4.2 per cent for chemical degradation; 11.6 m ha or: 3.6 per cent for physical degradation.

The major factors responsible for large-scale degradation are deforestation, unsustainable fuel wood and fodder extraction, shifting cultivation, overgrazing, non adoption of adequate soil conservation measures, improper crop rotation, indiscriminate use of agrochemicals such as pesticides, improper planning and management of irrigation system and extraction of groundwater in excess of the recharged capacity.

Since land and water will be shrinking resources for agriculture, there is no option in the future except to produce more food and other agricultural commodities from less per capita arable land and irrigation water. In other words, the need for more food has to be met through higher yields, per unit of land, water, energy and time. Hence, there is need to evolve a scientifically-based land use system, a sound CA policy, and mission-oriented programme.

According to the National Agriculture Policy, India must achieve a growth rate of 3-4 per cent per annum in the agricultural sector, and food grain production of 400 m.t. by 2020. The question is: how can this target and growth rate be achieved? This can only be achieved through mechanization, use of efficient machines and developing agronomic practices suited to agricultural machines and following CA.

Advantages of CA

- Reduces labour, time and fuel costs
- Reduces overall cost of operation
- Reduced use of fossil fuel leads to less environmental pollution
- Reduces soil compaction due to less trafficability
- More yields in dry years
- Savings in water
- Less soil erosion
- Less environmental pollution, carbon sequestration (green house effect)
- Less bleaching of chemicals and solid nutrients into ground water
- Less pollution of water
- Increased crop intensity
- Recharge of aquifers due to better infiltration

Disadvantages of CA

- Formation of hard pan below soil surface due to zero tillage and requires use of sub-soiler to break hard pan after 5-7 years
- Need to control weeds by using herbicides thus increasing cost
- Not suitable to all crop rotation systems
- May result in soil borne pests and pathogens in transition stage
- High cost of machinery such as laser land leveller, zero-till drill, strip till drill, raised bed planter, straw cutter cum incorporator, straw combine, straw baler, biomass digesters
- May also result in low yields

Scope of CA

Conservation agriculture has emerged as a new paradigm to achieve goals of sustainable agricultural production17. It is a major step towards transition to sustainable agriculture. The term CA refers to the system of raising crops without tilling the soil while retaining crop residues on the soil surface. The key elements which characterize CA include:

· minimum soil disturbance by adopting no-tillage and minimum traffic for agricultural operations,

· leave and manage the crop residues on the soil surface, and

· adopt spatial and temporal crop sequencing/crop rotations to derive maximum benefits from inputs and minimize adverse environmental impacts.

Combining the above elements with improved land-shaping (e.g. through laser aided levelling, planting crops on beds, etc.) further enhances the opportunities for improved resource management. In conventional systems, while soil tillage is a necessary requirement to produce a crop, tillage does not form a part of this strategy in CA. Intensive tillage in conventional systems causes gradual decline in soil organic matter content through accelerated oxidation, resulting in reduced capacity of the soil to regulate water and nutrient supplies to plants. Burning of crop residues, a common practice in many areas (e.g. rice–wheat cropping system) further causes pollution, GHG emission and loss of valuable plant nutrients. When crop residues are retained on the soil surface in combination with no tillage, it initiates processes that lead to improved soil quality and overall resource enhancement.

Benefits of CA are several fold. Direct benefits to farmers include reduced cost of cultivation through savings in labour, time and farm power, and improved use efficiency resulting in reduced use of inputs. More importantly, CA practices reduce resource degradation. Gradual decomposition of surface residues improves soil organic matter status, biological activity and diversity and contributes to overall improvement in soil quality. CA is a way to reverse the processes of degradation inherent in conventional agricultural practices involving intensive cultivation, burning and/or removal of crop residues, etc. CA leads to sustainable improvements in efficient use of water and nutrients by improving nutrient balance and availability, infiltration and retention by the soil, reducing water loss due to evaporation and improving the quality and availability of ground and surface water.

Conservation agriculture success world over

Conservation agriculture has emerged as an effective strategy to achieve goals of sustainable agriculture worldwide. It has the potential to address increasing concerns of serious and widespread problems of natural resource degradation and environmental pollution, while enhancing system productivity. According to current estimates, CA systems are being adopted in some 80 million ha, largely in rainfed areas and the area is expanding rapidly18. USA has pioneered research and development efforts and currently CA is being practised in more than 18 million ha of land. Other countries where CA practices are being widely adopted include Australia, Argentina, Brazil and Canada. In many countries of Latin America, CA systems are finding rapid acceptance by farmers. Many countries have now policy decision to promote CA. In Europe, France and Spain, CA was being adopted in about 1 m ha area under annual crops. In Europe, the European Conservation Agriculture Federation, a regional lobby group uniting national associations in UK, France, Germany, Italy, Portugal and Spain, has been founded. CA is also being adopted to varying extents in countries of Southeast Asia, viz. Japan, Malaysia, Indonesia, the Philippines, Thailand, etc. A unique feature which has triggered widespread adoption of CA systems in many countries is the community-led initiative strongly supported by R&D organizations rather than as a result of the usual research-extension system efforts19.

Conservation agriculture in India

In India, efforts to adopt and promote resource conservation technologies have been underway for nearly a decade, but it is only in the past 4–5 years that technologies are finding acceptance by the farmers. This effort has been spearheaded by Rice–Wheat Consortium for Indo-Gangetic Plains, a CGIAR ecoregional initiative involving several CG centres and the National Agricultural Research Systems of India, Pakistan, Bangladesh and Nepal. Concerns about stagnating productivity, increasing production costs, declining resource quality, declining water tables and increasing environmental problems are the major forcing factors to look for alternative technologies, particularly in the northwest region encompassing Punjab, Haryana and western Uttar Pradesh (UP)20. In the eastern region covering eastern UP, Bihar and West Bengal, developing and promoting strategies to overcome constraints for continued low cropping system productivity have been the chief concern. The primary focus of developing and promoting CA practices has been the development and adoption of zero tillage cum fertilizer drill for sowing wheat crop in rice–wheat system. Other interventions being tested and promoted include raised-bed planting system, laser-aided land-levelling equipment, residue management alternatives, alternatives to rice–wheat cropping system in relation to CA technologies, etc. The area planted with wheat adopting zero-tillage drill has been rapidly increasing21. It is speculated that over the past few years, adoption of zero-tillage has expanded to cover about 1 m ha. The rapid adoption and spread of zero tillage is attributed to benefits resulting from reduction in cost production, reduced incidence of weeds and therefore savings on account of weedicide costs, savings in water and nutrients and environmental benefits.

Adopting CA systems further offers opportunities for achieving greater crop diversification. Crop sequences/rotations and agroforesting systems, when adopted in appropriate spatial and temporal patterns, can further enhance natural ecological processes which contribute to system resilience and reduced vulnerability to yield, thus reducing disease and pest problems. Zero-tillage when combined with appropriate surface-managed crop residues sets in processes whereby slow decomposition of residues results in structural improvement of soil and increased recycling and availability of plant nutrients. Surface residues are also expected to improve soil moisture regime, improve biological activity and provide a more favourable environment for growth. These processes, however, are slow and results are expected only with time. In India, CA is a new concept and its roots are only now beginning to find ground. Globally, CA is being considered a route to sustainable agriculture and offers opportunities for moving to the next phase in Indian agriculture.

Transition to CA will not be easy

Conservation agriculture offers an opportunity and a mission to move into the next phase in Indian agriculture in the specific context. It is a challenge for all stakeholders, the scientific community, farmers, extension agencies and industry to understand the opportunities, and calls for strategies different from those we have adopted over the past decades in conventional agriculture. The biggest challenge is to overcome the past mindset according to which agriculture is nearly synonymous with the practice of cultivating the soil. CA paradigm will call for an innovation systems perspective to deal with diverse, flexible and context-specific needs of technologies and their management for specific locations. An innovation systems perspective involves understanding of the organizations and individuals responsible for generation, diffusion, adaptation, use of knowledge of socio-economic significance and the institutional context that governs the way these interactions and processes take place. R&D for CA thus will need innovative features to address the challenges. Some of them include.

Technological challenges

The CA system constitutes a major departure from the past ways of doing things. This implies that the whole range of practices, including planting and harvesting, water and nutrient management, disease and pest control, etc. need to be evolved, evaluated and matched in the context of new systems. The key challenge relates to development, standardization and adoption of farm machinery for seeding with minimum soil disturbance; developing crop harvesting and management systems with residues maintained on soil surface and developing and continuously improving sitespecific crops, soil and pest management strategies that will optimize benefits from the new systems.

Technology adoption

Strategies to promote CA will call for moving away from the conventional compartmentalized and hierarchical arrangements of research that generates and perfects technologies, extension that delivers it and farmers who passively adopt it. There will be need to bring all the involved stakeholders on a common platform to conceive end-to-end strategies. Institutionalizing the role of research, extension and farmers in such a way that the partnership among these stakeholders is strengthened right from the beginning, enabling a sense of ownership among them.

Long-term perspective

Conservation agriculture practices, e.g. no tillage and surface- managed crop residues set in processes which initiate changes in soil physical, chemical and biological properties, which in turn affect crop yields. Understanding the dynamics of these changes and interactions among physical, chemical and biological phases is basic to developing improved soil-water and nutrient management strategies. Similarly, understanding the dynamics of qualitative and quantitative changes in soil biodiversity, disease causing organisms, including weeds in relation to altered management practices is fundamental to evolving control measures with minimum use of environmentally harmful chemicals.

Site specificity

Adaptive strategies for CA will be highly site-specific, yet learning across the sites will be a powerful way in understanding why certain technologies or practices are effective in a set of situations and not effective in another set. This learning process will accelerate building a knowledge base for sustainable resource management. Developing and promoting a networking to share information amongst farmers, scientists and other stakeholders would be critical in advancing the spread and continued upgradation of CA systems. Understanding the diversity and context-specific nature of processes would be important in learning and changing for the better. CA implies a radical change from traditional agriculture. There is need for policy analysis to understand how conservation technologies integrate with other technologies, policy instruments and institutional arrangements that promote or deter CA23. Accelerated development and adoption of CA technologies will call for greatly strengthened monitoring and evaluation along with policy research. Understanding constraints in adoption and putting in place appropriate incentives for adopting CA systems will be important.

THE 3 PRINCIPLES OF CONSERVATION AGRICULTURE

CONSERVATION AGRICULTURE:

FOOD SECURITY IN LESOTHO FOR A CHANGING CLIMATE

1

Minimum tillage and soil disturbance

Direct planting involves growing crops with minimum soil disturbance since the harvest of the previous crop.
Direct planting can be used with all annual and perennial crops and vegetables.

Conservation agriculture can be done manually (i.e. likoti) or mechanically (i.e. animal or tractors drawn conservation agriculture planters).

Advantages of minimum tillage

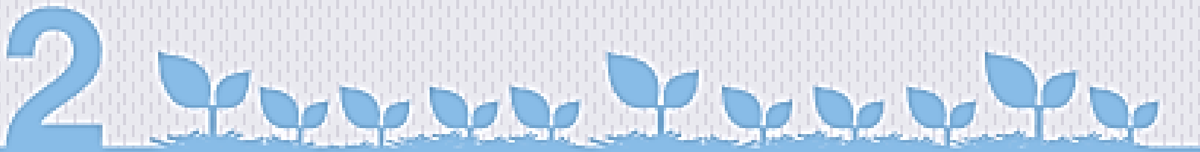
Protects the soil against erosion by water and wind

Cost savings: fuel, time and labour costs in the long term

Improves infiltration and conserves soil moisture

Improves soil organic matter

Increases yield per unit of fertilizer or manure applied. Long-term decreases the amount of fertilizer per hectare.



2 Permanent soil cover with crop residues and live mulches

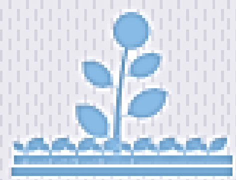
Mulch is any organic material (such as decaying leaves, bark, or compost) spread over the soil and around a crop to enrich and insulate the soil.

Live mulches are crops intercropped for purposes of providing soil cover.

Crop residue or live cover protect the soil from direct impact of erosive raindrops; conserves the soil by reducing evaporation and suppresses weed growth.

Advantages of permanent cover: residues and life mulches

Protects the soil from erosion by water or wind

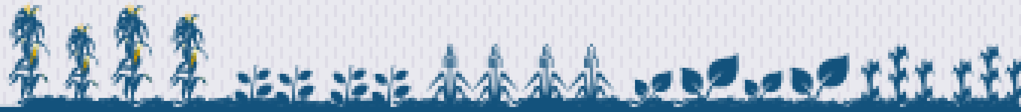


Suppresses weed germination and growth

Improves recycling of nutrients

Improves organic matter accumulation and carbon sequestration

3

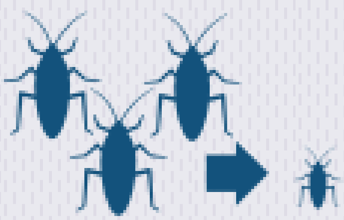


Crop rotation and intercropping

Crop rotation means that different crops are alternated in the same field, preferably cereals (maize and wheat) followed by legumes (beans).

Advantages of crop rotations and intercropping

Improvement of water use: crops with different rooting systems also utilize soil water at different soil depths.



Reduction of pests and diseases: different crops are susceptible to different disease and pest agents. Therefor, growing such crops in rotation will reduce the incidence of diseases and pests with no cost.

Improve fertility and production: crops have different rooting patterns which take up nutrients at different soil depths. Rotations help to utilize soil nutrients more efficiently. In addition, legumes fix nitrogen in the soil for the benefit of successive cereal crops in a rotation.

Environmental impact of integrated farming system

Food security, livelihood security, water security, natural resource conservation and environment protection have emerged as major issues worldwide. IFS was first propagated with the overall aim of establishing sustainable farming systems with reduction in exposure of the environment to pesticides and other agrochemicals. Adoption of organic farming was naturally expected to prevent short and long term ill effects on the biosphere. Prototype experimental farm studies have shown that not only the drastic reductions in pesticide use are possible but that subsequent careful selection of pesticides can also lead to minimizing the adverse environmental impact (Wohlfarth and Schroeder 1979). Programmes such as Linking Environment and Farming assist the farmers to move forward for sustainable practices through the adoption of integrated farming system management (IFSM). IFSM is targeted to bring a commitment to good husbandry and animal welfare along with efficient soil management and appropriate cultivation techniques using crop rotations and better seeds, reducing use of crop protection chemicals and fertilisers with the aim to maintain the landscape, rural communities and wildlife habitats. It is a dynamic concept with flexibility to adopt new technology and changing market pressures and consumer demands and to meet the future expectations through sustainable farming system which cares for the environment (Viaux 2001**)**. However, now there exist two schools of thoughts, one considering IFS as boon for environment while other takes it as curse.

Beneficial environmental effects

IFS increases the yield per acre significantly and at lower cost relative to conventional farming method. It helps in preserving the existing areas of woodland and rainforest habitats (and the ecosystems), which would otherwise vanish to meet the food and fibre demand through the conventional farming methods. This also leads to a reduction in anthropomorphic CO_2 generation as the preserved woodlands and rainforests efficiently remove it. Moreover, opportunity exists in IFS to harness methane emissions for generating heat and electrical energy which would help in reducing the use of fossil fuels for energy generation (EB 2010). It is quoted that "Integrated farming meets potentially conflicting challenges with sustainable development at farm level, in a manner that balances food production, profitability, safety, animal welfare, social responsibility and environmental care. It seeks to reinforce the positive influences of agricultural production whilst reducing its negative impacts. It is a means of achieving a sustainable agriculture and an indispensable part (but only a part) of sustainable development" (EISA 2001). Integrated farming makes a vital contribution to sustainable development by adding consideration of economic, ecological and social objectives to the essential business of agricultural food production (EISA 2001). During a long term impact analysis of IFS in Thailand it was revealed that the IFS has a higher diversity of enterprises, biodiversity, and activities than conventional farming (Gottingen 2006).

Environmental threats

Environmentalists fear that IFS can alter the local environment in several ways (EPA 2009). It is feared that IFS limits or destroys the natural habitat of most wild creatures, and leads to soil erosion, use of fertilizers may alter the biology of rivers and lakes feeding or draining the IFS. Some people fear that IFS is often not sustainable if not properly managed (can be seen at several places in India and abroad where the schemes were enforced on farmers without proper education) and may result in desertification, or sterilization of the land making it too poisonous and eroded to grow anything there. Another major concern is the recycling of antimicrobial resistant microbes in different components of the IFS leading to emerging of superbugs.

Studies have revealed that integrated fish farming seems to favour antimicrobial-resistant bacteria in the pond environment which is attributed to the selective pressure of antimicrobials there and to the introduction of antimicrobial resistant bacteria from animal manure (Petersen *et al*. 2002). This change may pose a potential risk of destabilization of natural microflora in the ecosystem which is ultimately deleterious to the environment. Experiments on 14^{C}-labeled CO_2 assimilation have revealed more deposition of 14^{C} in roots of barley in conventional system than in IFS, promoting better root growth and rhizodeposition required for long term soil fertility, indicating superiority of conventional system over integrated system of farming, though no such difference was evident with wheat cropping (Swinnen *et al*. 1995).

IFS associated health risk

Increasing health consciousness among the people has led to the increased demand for vegetable products grown in the absence of pesticides and synthetic fertilizers, popularly known as organic foods. Moreover, the land available for food production is decreasing day by day; so intensive cropping system and intensive livestock rearing system have come to merge into integrated intensive farming system to sustain the ever growing demand for food and feed. To get better yield, farmers augment soil fertility through application of compost and irrigation with sewage in most of the vegetable growing regions in India. In IFS model, the farm waste and sludge is circulated to get maximum benefit at the same point (Bhatt and Bujarbaruah 2005). Sewage and compost, being common sources of zoonotic pathogens, may contaminate soil with the pathogens and the transmission of infection through vegetable produce grown on contaminated soil is not rare. Studies on the dynamics of *Salmonella*, a zoonotic pathogen, in plants like cowpea, mung bean, vegetables and maize etc. reveal that the pathogen rapidly spreads to all parts of the plant within few hours of irrigation of crop with contaminated water (Singh *et al*. 2004, 2005a, b, 2006a, b, 2007ad, Siddiqui *et al*. 2006, 2008). The possibility of circulation of other sewage bacteria and potential or opportunistic bacteria becomes more apt in IFS model because of closely knit livestock, fishery and human components. Thus understanding the dynamics of spread of pathogens in different components of IFS is of need of the day to understand how these nasty pathogens persist in the nature. Integrated farming may result in origin of new pathogens or re-assortment of older ones into new forms. These are not merely fears but a few diseases are common in areas where integrated farming systems are more prevalent (Morse 1996). Influenza pandemic possibly originated from pig-duck agriculture, facilitating, reassortment of avian and mammalian influenza viruses. Japanese B encephalitis, malaria, dengue and yellow fever infections may spread widely from IFS hubs because IFS provides good breeding ground to mosquitoes, the vector for the infections.

Integrated farming in developing countries is similar to the factory farms of the western world. It is well known that pigs and other animals under such integrated intensive farming management may become carriers of methicillin-resistant *Staphylococcus aureus* (MRSA) and other dangerous pathogens due to many reasons, posing a serious health threat to the community. In most of the developed countries and developing countries that are taking lead in safe food production, emphasis is largely laid on safety of produce at all stages i.e. from farm to fork. Sanitary and phytosanitary (SPS) guidelines are to be followed at all levels of food production and processing (VETMED 2008, FAO 2008).

For safe food production in the IFS systems, we must understand the ecology of IFS units, their role as niche for infectious causes of disease in humans and animals, cycling of zoonotic bacteria therein and the strategies to decontaminate the units. In IFS, which has multiple components, the environmental or health risk associated with one compartment (subsystem) can readily spread to the other components. For example, the excreta from poultry or livestock suffering from some zoonotic infectious disease may be transmitted to the fish pond water or even to vegetable field, thus contaminating fish and vegetables which constitute important components of human diet (Siddiqui *et al*. 2006, Greger 2007,).

Risk mitigation strategies

Conventional farming systems in developing countries have severely neglected the negative impact of hazardous chemicals on human health and nature, but the environmental health awareness and concern are rapidly growing now. To overcome the problems of IFS model, FAO suggested action points are summarized as follows.

1. Registration of all IFS units
2. Training in inspection for official inspectors for quality of water at regular intervals
3. Training in good agricultural practices (GAP)/Code of Conduct (CoC) for IFS farmers
4. Training in good hygiene practice (GHP), good manufacturing practices (GMP) and Hazard Analysis Critical Control Point (HACCP) System for IFS farmers to process and handle the products
5. Technical assistance for all IFS farmers to follow GAP, CoC, GHP, GMP and HACCP
6. Monitoring IFS units for production standards through regular testing of samples of feed, drugs, chemicals used on IFS and also fish, ducks and livestock at IFS and their products
7. Controlling the IFS product movement
8. Documentation and certification of hatcheries; farms; feed, drug and chemical suppliers and handlers; and the suppliers and processors party to IFS for meeting the SPS requirements

To counter the bad effects of chemical use, IFS with integrated pest management (IPM) is the only way to maintain ecological balance in nature i.e. through organic farming.

Conclusion

In IFS model, whatever chemicals (insecticides, pesticides, herbicides, growth hormones, antibiotics etc.) are used in any one component of the system, they naturally reach the other components with minimum effect of leaching, dilution or decomposition at time scale. Most of these hazardous agro-chemicals used to enhance productivity contaminate soil and water and tend to bioconcentration. There is also urgent need to study the dynamics of pathogenic bacteria and hazardous chemicals circulating in various components of different types of IFS units (fish-duck, fish-pig, fish-cattle, fish-fodder-livestock, fish-vegetablelivestock etc.) to identify the possible intervention points to evolve of appropriate methodology for hygienic and safe food production from IFS in an ecofriendly manner.

Lecture 17. Cost reduction technologies and non monetary inputs in integrated farming system

Improved crop management practices help to get higher yields. At the same time, most technologies are also input intensive and labour intensive. As a result, cost of cultivation increases with escalation in cost of inputs and labour wages. This often proves to be deterrent for adoption of improved technologies. In the long run the rising cost of production may prove to be a disincentive for higher production. The motivation of the farmers to aim for higher yields may be dampened if the profits decline. Therefore, it is necessary to sustain higher yield levels at reasonable cost of cultivation.

In most crops, labour wages account for 50-60 percent of total cost of production and various inputs account for 40-50 percent. Any attempt to reduce cost must not result in yield loss. Cost reduction in crop production can be achieved through the following.

a. Improving labour efficiency and reducing labour requirement and cost.
b. Reducing the level of inputs used without affecting yield.
c. Adoption of low cost technologies.
d. Non - monetary inputs.

Low cost technology

It is a technology, which requires very little cost but help to get higher yield.

a. Seed / Seedling treatment for pest and disease control
b. Seed treatment for improving germination and population establishment
c. Seed hardening for inducing drought tolerance in rainfed crops.
d. Inoculation of bio-fertilizers through seed, seedling and soil.
e. Fertilizer use in nursery.
f. Placement of fertilizers
g. Use of growth promoters / growth regulators
h. Use of nitrification inhibitors to reduce loss of N.

Non - monetary input

It is defined as the cultural practice, which helps to achieve high yield at no extra cost and whose cost does not change with level of input. The following are some of the non-monetary inputs in crop production.

a. Crop varieties to suit region, season and soil conditions.
b. Land leveling and shaping for efficient water management in wetlands and garden lands and for moisture conservation in drylands.
c. Use of quality seeds.
d. Optimum time of sowing.
e. Optimum depth of sowing / planting
f. Optimum plant population.
g. Correct age of seedlings at planting.
h. Timeliness in field operations such as weeding, irrigation, fertilizer application, harvest, etc.
i. Ploughing across slope or along contour.

Agronomic measures for reducing requirement of labour and inputs
(Low and no cost technologies)

1. ***Tillage and land shaping***

a. Minimal tillage and zero tillage.

b. Off-season tillage

c. Labour saving implements and machinery.

d. Timeliness

2. ***Seeds and sowing***

a. Seed treatment

b. Sowing with seed drill

c. Relay sowing and ratooning.

3. ***Manuring***

a. Soil test based fertilizer recommendation.

b. Cropping system approach.

c. Bio-fertilizer application

d. Balanced use of nutrients

e. Form of fertilizer to suit soil condition and to reduce loss of nutrients.

f. Optimum time of application.

g. Correct method of application

h. Organic waste composting

i. Integrated nutrient management.

4. ***Crop protection against weeds***

a. Early weeding

b. Row sowing / planting to enable efficient manual weeding.

c. Use of tools to increase labour use efficiency.

d. Inter-tillage

e. Intercropping

f. Timeliness in application of herbicides.

5. ***Crop protection against pests and diseases***

a. Resistant / Tolerant crops and varieties.
b. Seed treatment.
c. Nursery protection
d. Biological control
e. Crop rotation and intercropping-
f. Summer ploughing.
g. Integrated pest management

6. ***Harvest and processing***

a. Timely harvest
b. Proper drying
c. Use of machinery to reduce labour and cost.