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Agroforestry farming systems in the homesteads of Kerala, southern India

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Abstract. Kerala State on the southwestern coast of India in the tropical humid zone has a predominantly agricultural economy, a very high density of population and therefore high pressure on cultivable land. The farmers there undertake cultivation of an array of crops – tree crops, plantation crops, seasonals and biennials – all in intimate mixtures on the same piece of land around the homesteads. Farm animals and poultry and sometimes fisheries also are essential components of the system. The close association of agricultural crops, tree crops and animals in the homesteads represents an excellent example of sustainable and productive agroforestry homegardens. Optimum utilization of available resources of land, solar energy and technological inputs and an efficient recycling of farm wastes are important characteristics of the systems. This paper attempts to describe and evaluate the systems' stability, productivity and sustainability, and identify its merits and constraints as well as research needs.

1. Introduction

Kerala State, which covers only 1.18 per cent of the total land area of India, supports over 3.5% of the country's population (census of India, 1981). The State with an area of 38,963 sq. km has a population of over 25 million, amounting to a density of 655 persons/sq. km, the highest among Indian States [18]. In the coastal and midland areas, population density often exceeds 1500 persons/sq. km. A large majority of the population of the State live in villages and depends on agriculture for livelihood. Because of the high density of population, the size of farm holding is very small, ranging commonly from 0.02 ha to 1.00 ha. The farmers of the State usually undertake intensive farming involving a variety of crops on the limited area available in order to obtain food, fuel, fodder, timber and cash from the homesteads. The homesteads thus present an excellent example of the basic concepts of agroforestry homegardens [2]. Coconut palm is an important component of these homegardens, and some publications based on crop

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combinations with coconut in the State have been brought out [8, 9, 13]. However, quantitative descriptions of woody components other than coconut and the homegarden systems involving them have seldom been attempted. In view of the importance of these components and systems of agroforestry homegardens in the livelihood of the people of Kerala, this paper attempts to describe the essential aspects of the structure and function of these farming systems and evaluate their potential for exploitation and development.

2. General description of the area

Kerala State is 580 km long, and lies between the Arabian Sea in the west and the Western Ghats in the east between 8°18′ and 12°48′ N latitudes and 74°52′ and 77°22′ E longitudes. It is broadest (120 km) in the middle, tapering to the northern and southern ends.

The land area of Kerala can be distinguished into three broad natural physiographic divisions, namely, 'highland', 'mid-land', and 'lowland', each running almost parallel to each other along the length. The mountainous land along the Western Ghats in the eastern side of the State is the 'highland'; it is under forests interspread with small streams and the region accounts for 48% area and 15% population of the State. The palm-fringed coastal belt with its picturesque backwaters, running parallel to the Arabian Sea with almost level topography constitutes the 'lowland' (10% area and 26% population) and in between these two lies the 'midland' (42% area and 59% population) intersected by numerous rivers, small hills and valleys.

The State as a whole has a humid tropical climate, so that the growth of vegetation is regulated mainly by rainfall. The rainfall is bimodal monsoon; the South-West monsoon from June to August accounts for the major share of the total annual rainfall. The North-East monsoon from October to January is also agriculturally very important. The mean annual rainfall of the State is 2960 mm, with a mean annual number of rainy days of 126. Rainfall is distributed relatively more uniformly over the rainy seasons in the southern parts of the State as compared with the northern parts, as a result of the influence of both the south west and north-east monsoons. The mean annual temperature throughout the State is around 27 °C, the peak temperatures being 29 °C–31 °C during March–May.

2.1 *Soils:*

The soils of the State have been broadly classified into four major classes, viz. Oxisols (50%), Inceptisols (25%), Entisols (20%) and Alfisols (5%). The major textural classes of Kerala soils and their general fertility status and physicochemical characteristics are given below [3, 5].

– Laterite (Oxisols): are generally poor in N, P, K and organic matter, are acidic (pH 5.0–6.2) and well-drained, and respond well to management practices.

– Red loam (Alfisols): are essentially kaolinitic in nature, acidic in reaction, highly porous and friable, and low in organic matter and essential plant nutrients.
– Coastal alluvium (Entisols): have been developed from recent marine deposits; the texture is dominated by sand fraction; are excessively drained with very rapid permeability and therefore leaching of nutrients is a major problem; improper drainage because of high water table is also a problem in many areas.
– Riverine alluvium (Entisols): occur mostly along the banks of rivers and tributaries and show wide variation in physicochemical properties depending upon the nature of alluvium deposit; are very deep with sandy or loamy texture; respond well to management.
– Greyish *Onattukara* (Entisols): have characteristic hydromorphic features like grey horizon, mottling streaks, hard pans, organic matter decomposition, Fe and Mn concretions, etc; are moderately supplied with organic matter, N and K, but are deficient in lime and phosphate; acidity is a problem.
– Hydromorphic saline (Entisols/Inceptisols): found in areas near backwaters and estuaries bordering the coast, where frequent inflow of tidal waters cause salinity; maximum accumulation of toxic salts takes place during summer months; these soils are imperfectly drained and in some areas, undecomposed organic matter in lower layers causes acidity.
– Acid saline (Inceptisols): very deep, drained, dark brown alluvial soils having silt loam to silty clay loam surface texture; the sub-soils show the presence of lime shells; the clay content decreases with depth; these soils are slightly acidic, medium in organic matter and poor in total and available nutrients; they are sometimes seriously affected by salinity.
– *Kari* soils (Inceptisols): these black and poorly drained, heavy textured soils resemble peat soils; decomposed organic matter is often observed in the lower layers; are highly acidic in reaction, the pH approaching 3.0 during summer months; accumulation of salts to toxic levels often affects crop growth and yield.
– Forest loam (Inceptisols): restricted to the highlands of the State; these soils are, in general, shallow; have dark brown to black-coloured surface soils due to the presence of organic matter; are acidic, rich in nitrogen and phosphorus, but poor in bases.
– Black soils (Inceptisols): are dark brown though low in organic matter, calcareous and moderately alkaline (pH 7.5–8.5), and clayey (50% clay), with high C.E.C.; they do not exhibit features of the typical Vertisols except for the cracking nature during dry periods; are moderately fertile.

3. Agroclimatic zones

The State is divided into eight major agroclimatic zones on the basis of topography, soils and sea-water intrusion (Figure 1) [3, 5, 17]. These are:

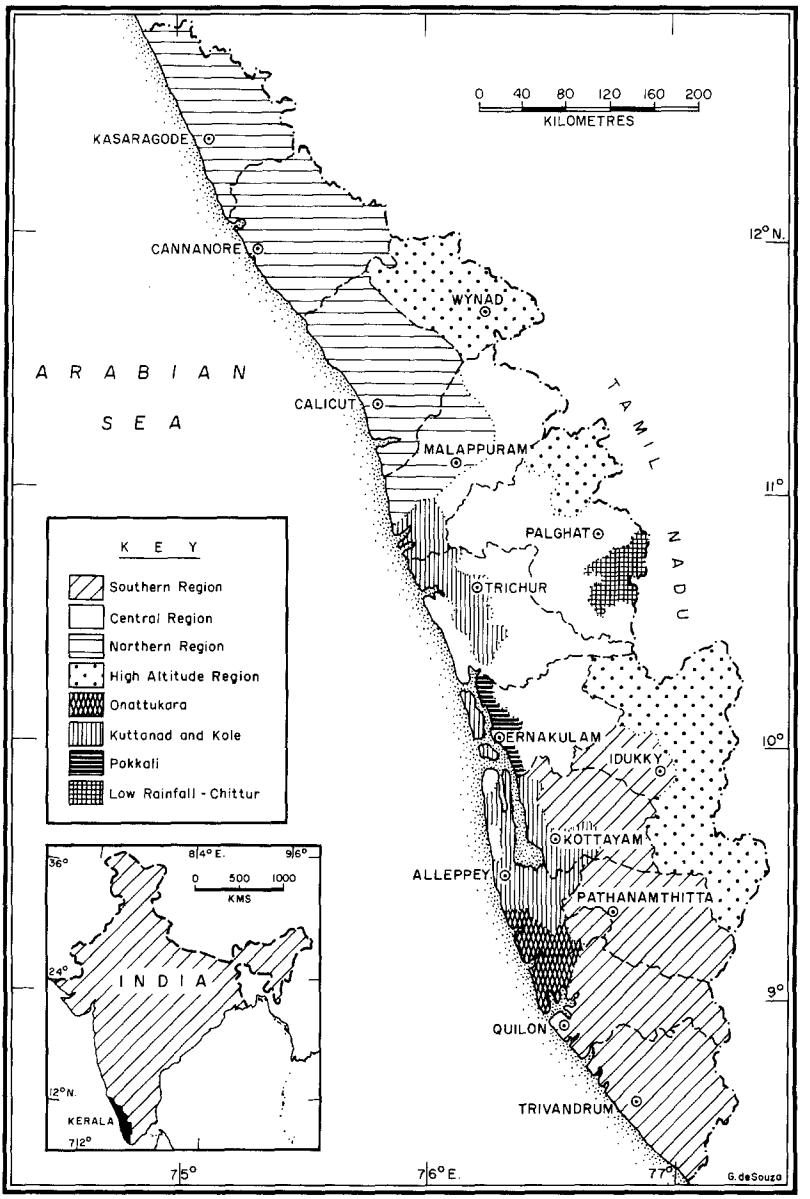

Figure 1. Map of Kerala showing the different agroclimatic zones.

– the Southern Zone: comprises the four southern districts; has plentiful seasonal rainfall in the coastal plains and a moist, hot weather in the interior region; the soils are predominantly laterite or red loam;
– the Central Zone: consists of three central districts, excluding the high ranges and coastal saline areas; being on the wind-ward side of Western Ghats, receives heavy rainfall though with erratic distribution; the main soil types are laterite, alluvium, and saline;
– the Northern Zone: consists of three northern districts; receives heavy rains during both the south-west and north-east monsoons; but December–May is very dry, the soils of the area are sandy loam, laterite or alluvium;
– the High Altitude Zone: comprises the two districts in the Western Ghats at an elevation of 700–2,100 m a.s.l. The bulk of the rainfall is received during the South West monsoon; the soils are mostly loamy forest soils; dense forests, steep hills and deep valleys are in abundance in this zone;
– the *Onattukara* Zone: located in the coastal belts in the southern districts of Quilon and Alleppey; consists of recent sediments of sand with level topography; salt water inundation is common in this area;
– the *Kuttanad* and *kole* Zones: the former represents a 60 km-long and 25 km-wide strecth of low-lying lands on the west coast, separated from the Arabian Sea by a narrow strip of land in the districts of Alleppey and Kottayam; the region experiences hot summer with plentiful rainfall and high humidity; it practically lies 2–3 m below sea level and is submerged under water for the major part of the year, and has acid sulphate soils. The *Kole* zone lies in Trichur and Malappuram districts in the central part of the State; it is also low lying along the coastal strips; has clay loam soils;
– the *Pokkali* Zone: located in the central part (Ernakulam District) of the State; comprises marshy areas where salt water incursion is a problem; lies at about mean sea level and is subjected to tidal waves and periodical inundation by saline water; the soils are of acid sulphate nature;
– the low rainfall zone: covers *Attappady* hills and eastern parts of Palghat District in the Northeastern part of the State; has a mean annual rainfall of 960 mm; the maximum temperature reaches about 44 °C in February–March; soils are Inceptisols.

4. Crops

An inventory of the major crop species/trees grown in the homesteads of the State and the production of major crops are presented in Tables 1 and 2 respectively.

5. Structure of the system

5.1 *Cropping system*

In Kerala, 21% of the cropped area is under irrigation. Due to the varied soil, land, physiographic and climatological factors, the cropping system of Kerala

Table 1. Inventory of crop species/trees in the homesteads of Kerala

Crops	Scientific name	Growth form/ economic produce	Main growing/harvesting seasons	Average production/ plant or unit area	Average market price/kg (Rupees*)
Food crops					
Arrow root	*Maranta arundinacea*	Perennial herb – Rhizome	May–January	8–10 t/ha	0.50
Cassava	*Manihot esculenta*	Shrub – tuber	May–January	5–15 t/ha	0.50
Chinese potato	*Coleus parviflorus*	Herb – tuber	April/May–December	10–12 t/ha	2.00
Dioscorea	*Dioscorea* spp.	Herbaceous climber – Tuber	May–January	12.5–25 t/ha	1.00
Rice	*Oryza sativa*	Grass – Grain	June–	2 t/ha	1.50
Sweet potato	*Ipomoea batatus*	Perennial herb – Tuber	June/July & Sept/Oct	12.15 t/ha	0.50
Taro	*Colocasia* spp.	Herb – Root	May/June–Oct/Nov	15–20 t/ha	0.50
Elephant Yam	*Amorphophallus campanulatus*	Herb – Tuber	February–December	15–20 t/ha	1.00
Pulses					
Cowpea	*Vigna unguiculata*	Annual herb – Grain	August–November	150–350 kg/ha	2.50
Horse gram	*Dolichos uniflorus*	Shrub–Grain	August–November	600 kg/ha	6.00
Mung bean	*Vigna radiata*	Annual shrub – Grain	August–November	300–500 kg/ha	6.00
Pigeon pea	*Cajanus cajan*	Perennial shrub – Grain	August–November	450–650 kg/ha	6.00
Fruits					
Anona	*Anona* spp.	Tree –Fruit	February–April	50 kg/tree	1.00
Banana	*Musa* spp.	Perennial herb – Fruit	June–March	1500 bunches of 20 kg each/(30 t)/ha	3.50
Bread fruit	*Artocarpus altilis*	Tree – Fruit	April–May	300 fruits (1–4 kg each)/tree/year	1.50
Garcinia/choisy	*Garcinia indica*	Tree – Fruit	June–July	100 kg/year	15.00
Gooseberry	*Emblica officinalis*	Tree – Fruit	November–January	10–15 kg/tree/year	2.00
Guava	*Psidium guajava*	Tree – Fruit	July–Aug. & Dec–Jan	500–800 fruits/tree/yr	3.00
Jack fruit	*Artocarpus heterophyllus*	Tree – Fruit	January–April	500–1000 kg/tree/yr	0.50

Mango	*Mangifera indica*	Tree – Fruit	February–March	100 kg/tree	4.50
Papaya	*Carica papaya*	Tree – Fruit	Perennial	30–150 fruits/tree/yr	1.00
Passion fruit	*Passiflora edulis*	Perennial climber – Fruit	Perennial	20,000 fruits/ha	2.00
Pineapple	*Ananas comosus*	Perennial herb – Fruit	February–April	–	3.00
Pomegranate	*Punica granatum*	Perennial shrub – Fruit	April–May	50 fruits/tree/year	6.00
Sapota	*Achras zapota*	Tree – Fruit	February–May	25 kg/tree/year	4.00
Tamarind	*Tamarindus indicus*	Tree – Fruit	March–April	200 kg/tree/year	12.00
Oils and fats					
Coconut	*Cocos nucifera*	Tree - fruit	At monthly or bimonthly intervals	40–60 nuts/palm/yr	1.50/nut
Groundnut	*Arachis hypogaea*	Annual herb – Kernel	April/May–Aug/Sept OR Dec/Jan–April/May	1200–1500 kg pods/ha	3.00
Sesame	*Sesamum indicum*	Annual herb – Seed	August–December	250–500 kg/ha	8.00
Beverages					
Cacao	*Theobroma cacao*	Tree – Bean	December–January	300 kg dried beans/ha	25.00 (dry beans)
Coffee	*Coffea* spp.	Tree or shrub – Bean	December	800 kg/ha	10.00 (dry beans)
Spices and condiments					
Cardamom	*Elettaria cardamomum*	Perennial herb – Seed	October/November	100 kg dried capsules/ha	150.00
Cinnamon	*Cinnamomum zeylanicum*	Tree – Bark	May/June–Nov/Dec	150–250 kg quills/ha/yr	50.00 (quills)
Clove	*Syzygium aromaticum*	Tree – Dried flower buds	January/February	2 kg dried buds/tree	150.00
Ginger	*Zingiber officinale*	Perennial herb – Rhizome	April–Jan/Feb	10 t/ha (fresh ginger)	10.00 (dry ginger)
Nutmeg	*Myristica fragrans*	Tree – Fruit	November–January	1500–2000 fruits/yr	70.00 (mace)
Pepper	*Piper nigrum*	Perennial woody climber – Fruit	January–February	2 kg green pepper/vine	40.00
Turmeric	*Curcuma longa*	Perennial herb – Rhizome	April/May–Dec/Jan	3–5 t dry turmeric/ha	8.00 (dry)
Vegetables					
Bhindi	*Abelmoschus esculentus*	Herb – Fruit	June/July–Oct/Nov	10 t/ha	2.00
Bitter gourd	*Momordica charantia*	Climber – Fruit	June/July–Oct/Nov	30 t/ha	3.00
Brinjal	*Solanum melongena*	Herb – Fruit	June/July–Oct/Nov	25 t/ha	2.00

Table 1. cont.

Crops	Scientific name	Growth form/ economic produce	Main growing/harvesting seasons	Average production/ plant or unit area	Average market price/kg (Rupees*)
Cucumber	*Cucumis sativus*	Trailing herb – Fruit	June/July–Oct/Nov	10–25 t/ha	1.00
Moringa	*Moringa* spp.	Tree – Fruit	March–May	10.00 kg/tree	3.00
Snake gourd	*Trichosanthes cucumerina*	Climbing annual – Fruit	June/July–Oct/Nov	35 t/ha	1.00
Watermelon	*Citrullus lanatus*	Creeper – Fruit	December – February	20–35 t/ha	3.00
Winged bean	*Psophocarpus tetragonolobus*	Perennial climber – Fruit	December–January	1500 fruits/ha	2.00
Fodder grasses					
Brazilian lucerne	*Stylosanthes guianensis*	Grass – Foliage	Perennial	10 t/ha	0.05
Guatemala grass	*Tripsacum laxum*	Grass – Foliage	Perennial	25–30 t/ha	0.50
Guinea grass	*Panicum maximum*	Grass – Foliage	May/June–Aug/Sept	20 t/ha	0.50
Napier grass	*Pennisetum purpureum*	Grass – Foliage	May/June–Aug/Sept	25–35 t/ha	0.50
Trees					
Bamboo	*Bambusa arundinaea*	Multipurpose tree	–	–	–
Erythrina	*Erythrina indica*	Multipurpose tree	–	–	–
Glyricidia	*Glyricidia sepium*	Multipurpose tree	–	–	–
Leucaena	*Leucaena leucocephala*	Multipurpose tree			
Mahogany	*Swietenia macrophylla*	Tree/Timber	–	–	–
Morinda	*Morinda tinctoria*	Tree/Timber	–	–	–
Portia tree	*Thespesia populenea*	Tree/Timber, Fruit	–	–	–
Teak	*Tectona grandis*	Tree/Timber	–	–	–
Wild jack	*Artocarpus hirsuita*	Multipurpose tree	–	–	–
Others					
Arecanut	*Areca catechu*	Tree – Fruit	December–May	5 kg nuts/palm	30.00/100 nuts
Betel vine	*Piper betel*	Perennial climber – leaf	–	2–30 million/leaves/ha	5.00/100 leaves
Cashew	*Anacardium occidentale*	Tree – Kernel	Dec/Jan–April	5 kg/tree/year	8.00 (raw nuts)
Lemon grass	*Cymbopogon citratus*	Perennial grass – leaf	–	50–120 kg oil/ha/yr	65.00 (oil)
Palmyrah palm	*Borassus flabellifer*	Tree	July–September	–	–
Rubber	*Hevea braziliensis*	Tree – Latex	April–December	500 kg dried rubber/ha	15.00
Vetiver	*Vetiveria zizanoides*	Perennial grass – Roots	Jan–Feb	5 t dried roots/ha/yr	5.00 (roots)

* 1 US $ = approx. Rs. 12.20 (April 1986)

Table 2. Area, production and productivity of important crops of Kerala State (1981–82)

Crop	Area (ha)	Production (tonnes)	Production (kg/ha)
Rice	806871	1339393	1660
Pulses	33910	22286	657
Pepper	108242	27511	388
Ginger	13447	34379	2556
Turmeric	3200	6027	1883
Cardamom	54516	2800	51
Arecanut	61251	10702 (m. nuts)	175
Tamarind	11329	24068	2124
Mango	60181	280017	4653
Jack	61037	248232000	4067
Banana	14068	182415	13022
Other plantains	35921	145112	4040
Pineapple	5373	66810	12435
Papaya	10267	61520	5780
Cashew nut	139960	78898	564
Sweet potato	5316	34674	6523
Tapioca	248069	3745412	15097
Sesamum	15037	4000	266
Coconut	666618	3006 (m. nuts)	4509
Lemon grass	6371	232	36
Coffee	35625	26687	460
Rubber	237769	139455	587
Cocoa	23381	2894	124

Source: (3)
Note: Productivity refers to monocrop stands.

have certain distinguishing features. The cropping systems are grouped into four major groups as: (a) coconut-based (b) rice-based (c) homestead-based and (d) cassava-based [9]; the homestead system forms the focus of this paper.

A homestead is an operational farm unit in which a number of crops (including tree crops) are grown with livestock, poultry and/or fish production, mainly for the purpose of satisfying the farmers' basic needs. Homestead farming is an age-old practice in Kerala, and is prevalent throughout the State.

Although the home gardens appear to be a mixture of trees, shrubs and herbs, a certain general pattern seems to exist [11]. Wide variation in the intensity of tree cropping is noticeable between home gardens situated in the same agroclimatic zone. This can generally be attributed to the differences in socio-economic conditions of the household and their response to externally determined changes, particularly prices of inputs and products, dependence on land, tenurial conditions, etc.

Table 3 shows the tree crop intensity in homesteads [11].

Table 3.

Size of holding (ha)	Mean tree cropping intensity*	Mean no of trees/ha
Very small (0.02–0.19)	50.52	620.8
Small (0.02–0.80)	37.79	276.8
Medium (0.81–2.00)	26.54	211.7
Large (2.00)	23.24	121.1

* expressed as the percentage of total area occupied by the tree canopies.
Source: (11)

It is seen from Table 3 that a reduction in the size of the holding has led to an intensification of cultivation. In such a situation, it is commonly noticed that as the intensity of tree cropping is increased, miscellaneous tree species having no immediate direct benefit are replaced with multiple use species such as *Leucaena.* Although this has reduced the species diversity, the intensity of cultivation of the selected species has considerably increased.

A schematic representation of the activity of an intensive homegarden is presented in Figure 2.

The components are so intimately mixed in horizontal and vertical strata as well as in time, that complex interactions exist among soil, plants, other components and environmental factors in the farmer's plot where he lives and manages the unit. The farmer chooses his crops and crop combinations based on his own wisdom and perceptions acquired over generations of experience, the criterion being his home requirements of food, fuel, fodder and timber. Cattle rearing is also undertaken in most of the homesteads, particularly in the suburban and rural areas as a complementary enterprise. More than 50% of the cultivated area in the State is under this system.

5.2 *Crop and tree components*

Among the crops grown in the homesteads, coconut is the most dominant and important. Known as 'Tree of Heaven' (*Kalpa Vriksha*), and 'Tree of a Hundred uses', coconut plays a vital role in the economy of the State. Kerala State has even derived its name from coconut – *Kera* in the local language *Malayalam* means coconut. Kerala alone accounts for 70% of total area and production of the crop in India. There are only two distinct varieties of coconut – the Tall and Dwarf of which the Tall is extensively cultivated for copra, oil and fibre. A number of hybrids and cultivars are also being developed and popularised. The growth characteristics and planting pattern of coconut palms facilitate successful growing of other crops in between or

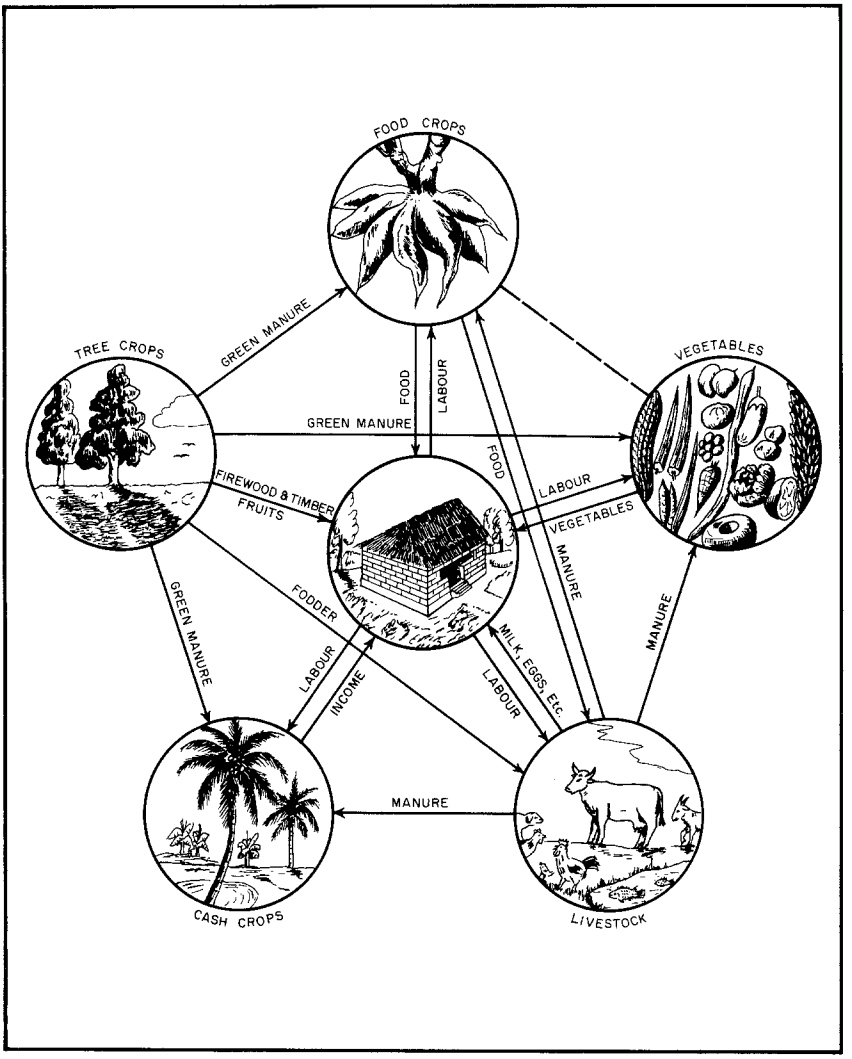

Figure 2. Schematic presentation of the interaction among major components of the homestead agroforestry system of Kerala.

under them [8, 13]. Further, the labour input for managing the crop is comparatively less than that for many other crops, which makes it an ideal crop for people engaged in other occupations. Intercropping and/or other forms of crop combinations with coconuts is a very common practice especially around the homesteads throughout the State.

The other important perennial crops in the homesteads are arecanut, black pepper, cacao, cashew and various tree species.

The arecanut palm (*Areca catechu*) is the main source of the common masticatory nut, popularly known as betel nut or *supari.* It is extensively used by all sections of people as a masticatory and for several religious and social ceremonies. This crop is grown mainly in areas with assured irrigation facilities, in homesteads situated in the valleys and plains.

Among the States of India, Kerala has almost a monopoly in the cultivation and trade of black pepper, 'the king of spices'. It is grown mostly as an intercrop in the homesteads using other tree crops as live standards. As a monocrop, it is grown in hilly regions using standards such as *Erythrina indica, Garuga pinnata, Leucaena, Glyricidia,* etc. Though a number of cultivars are grown, the most popular one is *Karimunda.* A high yielding hybrid known as *Panniyoor*-1 is now extensively grown in places with ample sunlight.

Cashew is yet another important export oriented crop grown as pure stand and also in the homesteads in marginal and submarginal soils in the Northern Zone. This tree crop is fairly drought-resistant and is common in areas where the rainfall is erratic and the drought is prolonged. The cashew nut processing developed as a cottage industry has enhanced the employment opportunities for the rural people.

Cacao is successfully grown with coconut and arecanut where irrigation facilities are available, and it is an economically attractive system. Tree spices like nutmeg, clove and cinnamon are very popular in the homesteads of the Southern Zone, where rainfall is more evenly distributed within the year. The upper storey growth of coconut provides enough shade and favourable microclimate for these crops.

Cultivation of ginger and turmeric is very popular in almost all the places in the State. Satisfactory yield in the partially shaded condition existing in the homegardens, fair market demand, easy processing and long storage life after processing are factors that encourage the farmers for wide-spread cultivation of these crops in the homesteads.

Coffee-based homestead system is a notable feature of the high altitude region. In this system, coffee is intercropped with perennial crops like black pepper, jack fruit and others. Of late, coconut has also been introduced in this region and forms an ideal shade crop for coffee especially in the early stages of growth of coffee [5].

Another important cash crop grown in the warm high-range region is cardamom. This species flourishes well in humid environments and requires dense shade for its proper growth. Trees like jack fruit, mango and tamarind provide excellent shade for the cardamom in the homesteads.

Rubber is grown in areas where the rainfall is evenly distributed in the hill slopes and also in the plains of southern region. In the initial stages of its growth a number of intercrops can be grown along with it, and it is fast becoming a tree crop of homegardens.

Among the tropical tubers, cassava and yam are the most common and

important subsidiary food crops. Cassava is grown in the homesteads under partially shaded conditions, with lesser tuber productivity compared to open area stands. Other tuber crops like taro, elephant foot yam, dioscorea, lesser yam, arrow root, sweet potato and chinese potato are more shade tolerant and hence give better results when grown in the homestead.

Banana and pineapple are also common fruit crops in the homesteads. A number of cultivars of banana are widely cultivated, *Nendran* being a very popular one. Pineapple is a common floor crop grown along with vegetables in the homegardens. The canning industries with pineapple open up avenues for employment for the rural people of the Central Zone. Further, a number of fruit crops like guava, papaya, annona, sapota, mango and jack fruit are also grown in most homesteads.

Pulses like red gram, cowpea, black gram, horsegram and oil seeds like groundnut, sesamum and castor bean are also common. The pulses give protein supplement to the rural diet. The commonly grown vegetable include bhindi (okra), brinjal, bitter gourd, cucumber, snake gourd, water melon and winged bean; these are grown for home consumption as well as for cash sale. Medicinal plants like lemongrass and vetiver are widely cultivated in some homesteads, especially in the Central Zone.

A home garden in Kerala, as perhaps in other places too, consists of a number of multipurpose trees having productive/protective functions, integrated into the system in different spatial and temporal arrangements. The various species of trees, mostly planted along plot peripheries, interact closely with agricultural crops. Among these, teak (*Tectona grandis*), a commercially valuable timber species, is common in the homesteads of 'midlands'. A few wild jack trees (*Artocarpus hirsuita*), Casuarina (*Casuarina equisetifolia*) as a windbreak in the homesteads of coastal tracts of the Northern Zone, and silver oak (*Grevillea robusta*) used as a shade tree for coffee in the high range region are the other common tree species in the homesteads. Moreover bamboo (*Bambusa arundinaca*) is commonly grown along the plot peripheries in the Central and Northern Zones. Known as the 'poor man's timber', this multipurpose plant plays an important role in providing building material for the poor in the villages, where they are widely used as posts, rafters and reepers in building construction, and bamboo thorns are used for fencing. Besides, bamboo mattresses are used as partition walls in the homes and also for drying grains; bamboo poles are used as a physical support for banana, and rural cottage industries like basket making are bamboo-based. Bamboo thorn for fencing is sold at Rs. 30 to 35 (U.S. $2.5 to 3) per head load, that can cover 10 metres [4]. A 10-metre long bamboo pole costs Rs. 40–50 in the market.

The portia tree (*Thespesia populenea*), numbering 5–10 per household, is a common sight in the homsteads of the South and Central regions and in the mangroves of the marshy, low-lying areas. The tree is often used as a live fence. The timber from this tree is of superior quality and is used for

agricultural implements, furniture and even for bullock carts.

Soft wood trees like 'Pala' (*Alstomia scholaris*), 'Matty' (*Ailanthus triphysa*), 'Elavu' (*Bombax ceiba*), are also planted along the boundaries of homesteads. Even the small-sized wood of these species find a ready market in the match industry which is a flourishing cottage industry in the State. A 'Matty' tree fetches about Rs. 100/- (US $8.00) for 8 years of growth [4]. Of late, *Albizzia falcataria*, a fast growing softwood tree is being popularly planted in the Southern Region, and is used for catamarans by the fishermen in the coastal tract. This tree fetches more than Rs. 120 (US $10.00) after 8 years. Often, fishermen offer 'fancy prices' for well developed trees. This tree is also being sold outside the State.

Mangroves form an essential part of the homesteads of backwater areas in the lowlands of *Pokkali, Kuttanad* and the coastal tracts of the Northern Zone. The mangroves protect the homesteads from mud and sand washed down by rivers and also from high tide. Often they constitute the boundaries between homesteads. A few mangrove species like *Acanthus illicifolius, Avicennia officinalis*, *Carbera odollam*, *Rhizophera conjugata*, *Rhizophera mucronata,* are commonly seen.

'Kaitha' (*Pandanus tectorius*) is seen extensively in the homesteads near canals and backwaters in marshy areas throughout the State. The leaves of this plant are extensively used for the manufacture of mats and fancy articles. The 'white bracts' are very fragrant. An oil called 'Keoro oil', is distilled from its roots and flowers and used in many Ayurvedic preparations. A number of small scale industries in the co-operative sector are flourishing based on this plant.

Some of the common crop associations are given as Figures 3–5.

5.3 *Mixed farming*

Most farm families possess in their homesteads a variety of animals – cows, buffaloes, bullocks, goats, sheep and birds like chicken and ducks. In certain places pigs are also reared. Cows and buffaloes are maintained for milk, bullocks for drought, chicken and ducks for eggs and meat. A homestead usually owns 1–2 cows/buffaloes and 15–20 chickens. In the Northern Zone, the homesteads will have 4–5 goats.

Fodder grass and legumes are widely grown to meet daily requirements of fodder to cattle; the important fodder grasses are Guatemala grass, napier grass and guinea grass (Table 1). Wherever rubber is grown, leguminous cover crops like *Calopogonium muconoides* and *Centrosema pubescence* are also raised as cover crops to enrich the soil and smother the weeds; their foliage can also be fed to the animals.

In the homesteads of backwater areas and coastal tracts ducks are common. Piggery is also practised in the homesteads of Central Kerala. Invariably each farm family possesses at least one pair of bullocks. But their number is dwindling due to the high cost of cattle feed/fodder.

Figure 3. Photograph of a coconut-based homestead; crops in the foreground include ginger, banana, elephant yam (*Amorphophallus companulatus*); the major tree species (other than coconut) include jack fruit (*Artocarpus heterophyllus*), moringa (*Moringa* spp.) *Erythrina indica,* and young mango trees. Black pepper vines are trailed on to coconut and Erythrina.

The waste materials from crops and homes are used as fodder/feed for animals/birds and the barn wastes are used as manure for crops. Because of shortage of fodder and grass and increasing cost of rearing cattle, the farmers do not retain the bullocks for a longer time: the usual practice is to buy the animals from the markets during the time of peak field operations, especially during June–July, and to sell them immediately after completion of field operations, usually at a lower price.

A number of improved breeds of cows like Jersey, Holstein and Brown Swiss are reared by farmers. A duck breed known as 'Khaki Cambell' is most common. Among the goats, a breed known as '*Malabari*' is the most popular one and among chicken, Austrolope, Rhode Island Red and White Leghorn are the ones commonly reared.

Authorized agencies in the Co-operative sector undertake collection and distribution of dairy and poultry products. These agencies also arrange to supply cattle/poultry feed.

In the study, conducted in a 0.12 ha plot of undeveloped arid land in mariculture is extensively practised with great success in the homesteads adjoining canals, paddy fields and ponds. The most important fishes/prawns grown are Catla (*Catla catla*), Rohu (*Labeo rohita*), Mrigal (*Cirrhina mrigala*),

Figure 4. Photograph of an arecanut (*Areca catechu*)-based homegarden, the components are somewhat similar to those of Figure 3. The house can be seen in the centre of the garden.

Figure 5. Mixed farming model of the homestead system. In addition to the multispecies multi-layer plant assocations, milch animals also constitute a major component of the system.

Pearl spot (*Etroplus suratensis*), Indian prawn (*Penaeus indicus*) and Tiger prawn (*Metapenaeus indicus*). As mentioned under 5.2, mangrove gardens of this region form an ideal habitat for fish farming. The organic wastes falling from these mangrove vegetation serve as a good feed for the fish and the numerous crevices in the border provide a good breeding place for the fish population.

A study conducted by the Kerala Gandhi Smarak Nidhi (a voluntary organization) in the homesteads, incorporating mixed farming concept reported the following [6]:

In the study, conducted in a 0.12 ha plot of undeveloped arid land in Trivandrum district of the Southern Zone, the farmer undertook a three tier planting of fodder, cassava, vegetables, a number of bananas, cloves and coconuts, with *Leucaena* being planted all around. There were 23 coconut seedlings, 12 cloves, 56 bananas, 49 pineapples and 30 pepper vines; fodder grasses were planted in a 0.03 ha plot. The rest of the land was covered by other crops. A cow which formed a part of the scheme not only provided milk for consumption and sale, but also organic manure. Chemical fertilizers were not used at all. The net income derived during the first three years (when the cash crop had not started yielding) amounted to Rs 1550/-, Rs 3848/- and Rs 3950/- in the first, second and third year respectively.

The expected net income from the cash crops at the current (1986) market price, when these crops start full bearing are: cloves: Rs 3800/-, coconut: Rs 900/-, other plants; Rs 1500/-, livestock: Rs 3000/- all adding up to a total of Rs 9200/- per year from the 0.12 ha plot.

This case study provides a good example of a sustainable organic farming system, which could be used as a model for future developments.

Beekeeping is also popular in some homesteads, especially of relatively more resourceful farmers.

6. Interaction between components

A typical homestead with a multitude of crops presents a multitier canopy configuration (Figures 3–5). The leaf canopies of the components are arranged in such a way that they occupy different vertical layers with the tallest component having foliage tolerant of strong light and high evaporative demand and shorter components having foliage requiring or tolerating shade and high humidity [8]. The major portion of the upper canopy goes for coconut. This is followed by other crops like black pepper, cacao and tree spices. The lower storey of the harvesting plane is occupied by banana, and cassava and other tuber crops. At the floor level, pineapple, vegetables and other herbaceous crops are grown. The canopy architecture and pattern of component interaction are similar to those of other tropical homegardens as described by Fernandes et al. [1], Fernandes and Nair [2], and Soemarwoto [15].

Wherever coconut is present as the dominant component, the intercrops that are grown vary according to the age and canopy size of coconuts.During initial stages of coconut's growth, all sun-loving crops form the lower tier. From bearing stage (8 years) to about 25 years of coconut, when the shade is rather dense, shade loving crops like yams, turmeric, ginger and so on, are grown. Afterwards the incoming solar radiation in the garden increases and the homestead can be filled with a number of annual and perennial crops.

7. System functioning

Out of 3.5 million operational holdings in Kerala, nearly 3.1 million (87% are very small (< 1.0 ha size), with an average size of 0.22 ha. These account for 42 percent of the total area under cultivation. Another 24% of the cultivated area has small holdings of 1–2 ha size. This situation of a large number of the holdings, as well as a large proportion of the cultivated area under them, has significant implications on land productivity and income [4]. The intensity of cropping in the homesteads is very high, and mostly with rather low levels of biomass productivity of individual components.

7.1 *Labour utilisation potential*

On an average each household consists of 6–8 people who provide the necessary workforce. In the small holdings, planting, cultural operations and harvesting of different crops occur throughout the year and are attended by the farm family. Most of the crops in the homegarden are labour-intensive except coconut.

As compared to monocropping, the homesteads involve high labour utilisation. For example, the average requirement of labour on a one-hectare homegarden with an intensive crop mix with livestock is about 1000 man days per year as compared with 150 man days for coconut monocropping and 400 man days for rice monocropping [8, 12, 16]. During certain seasons, such as during sowing and/or harvesting of different crops, an acute shortage of labour is a common experience. Coir industry, cocoa processing, cassava industry, fruit canning, jaggery making, match industry, etc. offer greater scope for employment for people, and the raw materials for all these are provided mostly by the homegardeners.

In addition to the above, there are also immense possibilities for employment for rural people by way of plaiting of coconut leaves for thatching the houses, basket making and mat making from bamboo and Pandanus; distillation of vetiver and lemongrass oil; fishing, milking, etc.

7.2 *Capital*

Income for the livelihood of the farmers is mainly by the sale of cash crop products like rubber, coconut, pepper, cashew, ginger, turmeric, cacao, etc., and surplus paddy.

Invariably for all farmers, July–August becomes a lean season so far as cash is concerned. That is the time when expenses are at their maximum and income from the crops is minimum: this period coincides with the South-West monsoon when planting and cultural operations of most crops take place; added to this the schools re-opening at this time and with an average of at least 2 school going children from every family, the farmers have to incur a lot of expenditure by way of school uniforms, books and other expenses. To meet the immediate cash requirements, the farmers try to sell all disposable farm animals such as poultry, goat/sheep, cows, buffaloes, etc., and also borrow from village money-lenders, at excessive interest rates. The loans will be repaid at the time of the harvesting of cash crops – arecanut, coffee, cashew, pepper, ginger, turmeric, etc. – during December–January. Most of the farmers save money chiefly for meeting the children's education expenses or for the marriage of girls. High expenditure on marriage is the most important social expense. Besides giving bridal dowry, heavy expenditure is also required to be incurred for the actual celebration of the wedding because of social compulsions.

Rural credit for agricultural purposes is well developed in Kerala, which is intended to disburse short-term, medium-term and long-term agricultural loans for agricultural operations. Agricultural credits are being arranged through co-operative banks and agricultural credit societies at the primary level. Even fertilizers, agricultural implements like tillers, tractors, pump sets, etc. and other inputs can be arranged to be obtained through these societies.

7.3 *Inputs*

Farmers usually store seeds from a current season's crops for the following season(s). Seed materials/seedlings are also obtained from authorized governmental agencies such as the State Department of Agriculture, Agricultural University, etc., and also from private suppliers, all at reasonable prices. Chemical fertilizers are increasingly being given for all crops. However, the plant protection chemicals are not widely used.

7.4 *Marketing*

The production and marketing processes in Kerala, in a way, are intertwined in the economic system in as much as the farmer has a significant influence on the production activity. The major commodities involved for marketing are arecanut, cacao, coconut, coffee, cashew, ginger, pepper, rubber, turmeric and vegetables. In the case of commodities which are not marketed through organized channels, the annual price fluctuations are quite substantial and the farmers are put into very great disadvantages [18].

In respect of a large number of agricultural commodities, a major portion of the trade transaction takes place in villages where they are produced. About 200 markets in Kerala conduct daily, weekly or biweekly sales

and purchases. There are also about 90 primary marketing societies in the co-operative sector. These approved agencies arrange procurement of produce from the farmers and this enables the farmers to fetch fair prices. Other than this, there are commission agents, middlemen and brokers, wholesale merchants and retailers to operate the market. The main market practices are negotiation, bargaining, commission basis and auction sale [18].

There are also problems relating to absence or lack of grading at primary level, lack of storage and transport facilities, lack of proper market intelligence, defective weighment, adulteration, etc.

8. System dynamics

Being a densely populated State, the pressure of population in Kerala is reflected in the agricultural activities and dynamics of the homesteads. There is practically no scope for increasing the area under plough. Therefore, agricultural and other land-use strategies aim at increasing the productivity of area under cultivation through exploitation of the available resources. This applies to homestead gardening also.

There have been some noticeable trends in the cropping patterns of Kerala over the past few years vis-a-vis market price of commodities, social changes and attitudes of the people and so on. Large scale introduction of cacao in the homesteads was done in the late 1970's when the price of cocoa in the Indian market touched an all time high of Rs. 45 (then US $5.50) per kg of dried beans [18]. But in subsequent years, to the great dismay of farmers, there was a sharp decline in cocoa prices, resulting even in the removal of cacao plants from the homesteads. Now, cacao is being replaced by fodder grasses, banana and tuber crops. Similarly, the area under arecanut had also decreased a few years earlier consequent to the decline in its price. The main food crop of rice faces innumerable constraints with its production, such as scarcity of labour, high cost of inputs and very low prices for the produce. This has forced many of the farmers to switch from rice to coconut. However, there is also another reason for this shift: coconut being a 'lazy man's crop', much attention is not required for its day-to-day maintenance. In Kerala, there is a tendency to seek 'white-collar' jobs in Government or private sectors, with the result that educated members of the family may not usually be available for agricultural operations. Under the circumstances, farmers go for cultivation of coconut in preference to labour-demanding rice crop. In the uplands of the low rainfall areas, palmyrah has been the main crop. Nowadays, they are also being replaced by coconut, consequent to the commissioning of irrigation projects in those areas.

An area of about 0.15 million ha in Kerala is affected by the so-called root (wilt) disease of coconut – a malady of uncertain etiology. Reduction in yield of root (wilt) affected palms is estimated to vary from 10–80% [13]. Because of this, the net returns from the disease-affected coconut gardens

steadily decrease. Intercropping with suitable crops is considered an effective way of increasing the economic returns from such coconut areas. So, systems of mixed farming in disease-affected coconut gardens, involving fodder grasses and legumes for building up and maintaining soil fertility, are being tested and popularised.

Rubber is the only one commodity in the State, the prices of which have been steady in the market for the past few years. For this crop, labour input is comparatively less once the tree attains the tapping stage. This has tempted many farmers to undertake cultivation of rubber, even in the homesteads. Banana and tuber crops are also slowly being replaced by rubber in areas where distribution of rainfall is uniform.

Black pepper, an important cash crop and foreign exchange earner, is being grown using coconut, arecanut and *Erythrina* as live standards. However, this practice is posing problems at the time of harvest of coconut and arecanut as the climbers find it difficult to climb the trees due to the presence of pepper vines on the trunk. *Erythrina* on the other hand, is frequently infested by stem borers which destablises the bearing pepper vines. Therefore concrete pillars and teak poles are also being used as standards; but they are excessively expensive. Of late, *Leucaena* (var K-8) and *Garuga pinnata* have also been tried as live standards for black pepper. *Leucaena* being a multipurpose tree crop holds much promise.

The current cattle population in the State is 3.4 million adult units, which require more than 5.6 million tonnes of fodder [18]. But the total fodder production in the State is estimated to be only 4 million tonnes, which includes dry straw, crop residues, weeds, etc. In order to fill up this large deficit of 1.6 million tonnes, a promising way is to grow fodder grass in the homestead, possibly through integration of pasture, livestock and tree crops. Growing of forage grasses and legumes, feeding them to cattle and recycling the dung and other basic wastes to crops as manure is an existing practice. This has helped to maintain the prolonged productivity of coconut palms by improvement in the physical, chemical and biological properties. The use of fermented cowdung for generation of biogas for meeting domestic fuel needs of farm families is also now getting popular. Though the biogas plant requires some initial expenses for its establishment, it needs no running expenditure. The practice reduces the demand for wood fuel; moreover, the slurry from gas plant can be used as enriched farmyard manure for the crops in the homesteads.

In the back-water areas and coastal regions, intensive mixed farming with fish culture is also practised. The cattle dung and poultry litter are dropped in the adjoining canals/tanks where fish is grown. In return, the excess fish is fed as fish meal to poultry and cattle. In the *pokkali* region, where rice cultivation is done in stagnant water of up to one metre depth, prawn culture is successfully practised. Only one crop of rice is taken in these fields and the stubbles of the straw are used as feed to the prawns. Often, farmers benefit

more from the prawn culture than from rice culture. One hectare of land can thus produce 2000 kg rice and an estimated 750 kg prawns (selling at Rs 10 per kg), per year, the total returns being Rs. 11500/ha and the expenses, excluding family labour, Rs. 4990/year. [7, 16] (1 US $ = approx. Rs. 12.20; April 1986).

9. Evaluation

9.1 *Merits*

The multitude of crop species in the homesteads helps to satisfy the primary needs of the farmer, such as food, fuel, fodder, timber and cash. This also helps to conserve the fertility by nutrient cycling in spite of the high intensity of cropping(s) [10]. The increased microbial activity in the rhizosphere of crops is another positive contribution in the multicropping system [12]. High labour utilisation and risk minimisation are the other benefits associated with the system [8].

Mixed farming practice causes substantial improvements in the physical, and biological characteristics of the soil [13]. The use of waste materials for feeding the cattle, poultry and fish results in efficient recycling of these wastes, whereas, increased utilization of family labour in this enterprise reduces the expenditure on hired labour. Adoption of mixed farming practices in the root (wilt) affected areas (of coconut) has helped to enhance the productivity of the the coconut palms as well as of the land [13]. The homestead system also causes less exposure of the bare soil to the beating action of the torrential rains experienced in these tracts, and consequently leads to reduction in soil erosion [9, 10].

9.2 *Constraints*

In order to sustain high levels of production from this intensive system, inorganic fertilizers are to be used despite the recycling efforts. This leads to an increase in the cost of cultivation.

In spite of the increased family labour utilisation, labour scarcity is being experienced at times especially during periods of peak agricultural operations.

Because of the scarcity of land it becomes difficult to earmark separate areas for production of forage crops. The growth of fodder crops is rather poor under shade [14].

Lack of irrigation facilities often limits crop production especially in areas where there is uneven distribution of rainfall as in the Northern Zone [3].

The rapid conversion of rice fields into coconut gardens is leading to the danger of a decline in the food production in the State. Even at present more than 50% of the food requirements of the State is met by import from the neighbouring States; conversion of more rice fields to other crops would

further reduce rice production in the State.

In the homestead polyculture, plant arrangement is usually in a haphazard manner without giving adequate attention to the ecophysiological requirements (water, light nutrients, etc.) of the individual understorey crops in the system, and thus leading to a reduction in the yields of individual crops.

The high plant density in the homesteads leads to excessive humidity within the plant community [8] that can cause the incidence of fungal diseases like bud rot (*Phytophthora palmivora*) of coconut, especially during rainy seasons.

The farmers of the State have a general feeling that the trees will take away all nutrients and cast shade, adversely affecting field crops. They also entertain a notion that the trees will harbour injurious birds and insects [4].

Lack of adequate research results is one of the major constraints for not favouring tree crops in the homesteads in certain places.

10. Potential and prospects

Planting of a number of multipurpose fruit trees such as mango, jack fruit, gooseberry, portia tree, wild jack, etc. in the homesteads provides the basic needs of food, fuel, fodder, timber and manure for the farmer.

Introduction of crops like *Leucaena* for fuelwood in the homesteads would help the farmer to tide over the energy (fuelwood) crisis. Pulses, vegetables and fruit crops in the homesteads provide a diversity in food products and improve the quality of diet of the farmer. This is particularly important in rural areas where the people are under-/mal-nourished.

There is scope for limited mechanisation in the homesteads as evidenced by use of tractors and power tillers for preparatory cultivation for rice and equipments and machinery for coconut climbing and dehusking.

Recycling of organic materials envisaged in the mixed farming system aims at conversion of waste materials into useful products for agriculture and other needs.

11. Research needs

In spite of the importance of these systems to the economy of the State and its people, practically no research has been undertaken to improve the productivity of these homegardens. Whatever research results are available pertain to monocrop systems so that they are of little value in these polycultural situations. The following are some of the research aspects that merit immediate attention.

Evolving shade tolerant varieties of fodder grasses and legumes and standardisation of their management.

Water and nutrient requirements of crops in a polycropping system.

Rooting pattern and root distribution studies of the component crops for understanding nutrient-moisture interaction and utilisation.

Spatial and temporal arrangement of crops for efficient conversion of solar energy.

Identifying crop associations which can be fitted into different intensities of shade.

Integrated production approach to be worked out involving crop/livestock/microbes/fertilizer/pests.

Extrapolability of one system into similar agro-ecological zones and working out economic analysis.

Complementary and competitive interaction effects between crop components.

Along with studies on the above aspects, research on various aspects on the related system also need to be intensified.

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