NUTRIENT CYCLING AND SOIL PRODUCTIVITY STUDIES OF HOMESTEAD AGROFORESTRY SYSTEMS OF SOUTHERN KERALA

By

JOISE ABRAHAM

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DECLARATION

I hereby declare that this thesis entitled "**Nutrient cycling and soil productivity studies of homestead agroforestry systems of southern Kerala**" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar title of any other university or society.

Vellayani

19-07-1997

JOISE ABRAHAM

CERTIFICATE

Certified that this thesis entitled "Nutrient cycling and soil productivity studies of homestead agroforestry systems of southern Kerala" is a record of research work done independently by Mr. JOISE ABRAHAM under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

Dr.M.ACHUTHAN NAIR,
Chairman,Advisory committee,
Associate Professor of Agronomy,
College of Agriculture,
Vellayani, Thiruvananthapuram.

Vellayani,
19 - 07 - 1997.

APPROVED BY

CHAIRMAN

Dr. M. ACHUTHAN NAIR

MEMBERS

Dr. G. RAGHAVAN PILLAI

Dr. N. MOHANAKUMARAN

Dr. S.K. NAIR

EXTERNAL EXAMINER

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JOISE ABRAHAM

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LIST OF ABBREVIATIONS

Ca	calcium
cm	centimetre
et al.	and others
Fig.	figure
g	gram
$g.\ cm^{-3}$	gram per cubic centimetre
ha	hectare
HP	Horse power
Hrs	hours
K	potassium
kg	kilogram
$kg.ha^{-1}$	kilogram per hectare
$kg.ha^{-1}.yr^{-1}$	kilogram per hectare per year
l	litre
m	metre
m^2	square metre
mm	millimetre
N	nitrogen
No	number
Nos	numbers
P	phosphorus
ppm	parts per million
Rs.	rupees
t	tonnes
$t.ha^{-1}$	tonnes per hectare
$t.yr^{-1}$	tonnes per year
viz	namely
^0C	degree celsius
%	per cent

INTRODUCTION

INTRODUCTION

Agroforestry is a sustainable land management system which increases the overall yield of land, combines the production of crops (including tree crops) and forest plants and/or animals simultaneously or sequentially on the same unit of land and applies management practices that are compatible with the cultural practices of the local population.

Agroforestry systems vary from region to region. Homestead farming is one of the traditional agroforestry systems practiced in Kerala state, where the size of farm holding is comparatively small.

Homestead is an operational farm unit in which a number of crops (dominated by tree crops), livestock, poultry and/or fish production is carried out mainly for satisfying the needs of the farmer (NARP status report, 1984). More than 80 per cent of the produce raised in a homestead is consumed within the home itself and the remaining 20 per cent is sold outside to generate subsidiary income to the farmer. The farmer utilises the area available around the house for different enterprises, based on the home requirement, with out any scientific basis.

The multipurpose trees included in the agroforestry systems act as nutrient pumps and they bring the subsurface nutrients to the soil surface by different plant cycling processes. However, the extent of nutrient recycling by various processes has not yet been scientifically studied so far.

Harvested produces of crops export considerable quantities of nutrients from the soil. As the sustainablity of a homestead is the balance between nutrient addition and nutrient removal from the system, quantification of the same is very necessary to adopt appropriate management practices. However, reports of such studies in the home gardens of Kerala are scanty.

Trees in agroforestry systems are known to influence the microclimate in the system. Information on the impact of trees and intensive cropping on the microclimate of homesteads are also lacking.

An understanding of the influence of light intensity and light penetration through different tree species is essential to effectively plan intercropping in home gardens, for maximum production and profit. Because of the lack of scientific information, recommendations could not be made so far, to improve the productivity of homesteads. Under these circumstances, the present investigations were undertaken in a homestead in Thiruvananthapuram district of Kerala State, with the following objectives :-

1) To take up an inventory of the biological components of the homestead
2) To evaluate the management practices
3) To study the nutrient cycling in the homestead
4) To study the changes in physical, chemical and biological properties of the soil
5) To study the changes in microclimate as influenced by the trees in the system and
6) To study the economics of the homestead.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

With increasing awareness of the significance of agroforestry, research on this subject was started in the tropics recently. Investigations on the potential role of trees in agroforestry systems were undertaken in different parts of the world. Even though, numerous research findings are available on nutrient dynamics of forest ecosystems, the role of nutrient cycling in the productivity of agroforestry homegardens has not been systematically studied so far. Reports on the changes in the physical, chemical and biological properties of the homestead soil and studies on microclimate, light penetration and economics of the homestead systems are very few. A review on research results on relevant aspects related to homestead agroforestry systems and related matters is given below.

2.1 Homestead agroforestry systems: definition and structure

Soemarwoto and Soemarwoto (1984) defined home garden as an agroforestry system which ideally combines the ecological functions of forests with those of providing the socio-economic needs of the people.

Ninez (1984) defined homestead production system as a sub system which aims at the production of house hold consumption items either not obtainable, not readily available or not affordable through field agriculture. Nair and Sreedharan (1986) defined homestead as an operational farm unit in which a number of crops (including tree crops) are grown with livestock poultry and / fish production mainly for the purpose of satisfying the farmer's basic needs.

Hanman (1986) referred to homesteads as the home and its adjoining land owned and occupied by the dwelling unit of the household including the immediate area surrounding the dwellers unit and the space used for cultivation of trees and vegetables . Stoler (1978) referred to the term mixed garden or house garden for the homestead gardens.

Fernandes and Nair (1986) stated that home gardens are characterised by a mixture of several annual or perennial crops grown in association, exhibiting a multi-layered vertical structure of trees, shrubs and ground cover plants which recreates some of the properties of nutrient cycling, soil protection and effective use of space above and below the soil surface.

Stoler (1978) reported that with growing pressure on land, decreasing cropped area per head, the proportion of land under home garden has been increasing up to 75% of the cultivated land. It was further reported that with the decline in size of holdings, income was increasingly sought from off-farm employment. This has resulted in a reduction in the cultivation of annual crops and increased the cultivation of trees and perennials which needed less labour.

Nair (1984) found that home gardens are known for their stable yields, very varied products, continuous and repeated harvests. He reported that inclusion of woody species in the farmland reduced various undesirable processes of soil degradation and productivity decline.

The study conducted by Fernandes *et al.* (1984) revealed that the size of the Chagga homegardens of northern Tanzania ranged from 0.2 to 1.2 ha with an average of 0.68 ha. According to Nair and Krishnankutty (1984), Kerala had a high density of population which resulted in small size of farm holdings. The size of the holdings ranged from 0.02 to 1.00 ha. Jacob and Alles (1987) reported that the Kandyan garden in Sri Lanka represented a home garden system practiced in small homestead holdings and their size varied from 0.4 to 2.0 ha with an average of 1.00 ha. The most important tree crops in the system were arecanut, jack and coconut.

Nair and Sreedharan (1986) found coconut as the most dominant and important tree crop in the Kerala homesteads. The other major perennial crops in the homesteads were arecanut, black pepper, cocoa, cashew and various tree species among one hundred crop / tree components. The most important multipurpose trees in the home gardens of Kerala were identified are teak, jack, casuarina, portia, silver oak, wild jack and silk cotton. Happy Mathew (1993) in a study on the agronomic resources inventory of a home garden in the southern zone of Kerala reported that multipurpose trees in a typical homestead included coconut, jack, mango, portia and bread fruit intercropped with a multitude of crops including elephant foot yam, cassava, dioscorea, ginger and fodder grass resulting in a cropping intensity of 156 per cent.

Abdul Salam *et al.* (1991) found that the crop livestock component in a 0.2 ha holding studied by them in the coastal uplands of south Kerala interacted synergistically to increase productivity and generated more returns and maintained soil health.

Fernandes and Nair (1986) felt that the structural complexity, the species diversity, the multiple output nature and the tremendous variability in the home gardens make them extremely difficult to work with, according to the currently available research procedures.

2.2 **Nutrient cycling**

One of the main principles of soil management in agroforestry is to make the best use of its resources - conserving and resource - sharing potentials. The main advantage of trees in a homestead is that the trees will act as nutrient pumps. The addition of nutrients, by cycling, that takes place to varying degrees in all land use systems, become particularly relevant in the homestead agroforestry context because of the likely effects of trees on such processes. Closed nutrient cycling known to operate in mixed ever green natural forests is not strictly operative in homestead agroforestry systems (Nair, 1984) because of the frequent harvesting.

Will (1959) reported that nutrient cycling is an important aspect that has to be considered while deciding the management practices for any agroforestry system and in most tree species significant quantities of nutrients are accumulated and cycled through litterfall, stemflow and throughfall.

According to Switzer and Nelson (1972), three principal mineral flow pathways affect the nutrition of terrestrial communities. They are geo-chemical, bio-geochemical and bio-chemical cycling. The major bio-geochemical processes are nutrient uptake by plants and its return by litterfall, stemflow and throughfall.

One of the important advantages of agroforestry is that the trees act as nutrient pumps. Transfer of nutrients from plant parts to soil takes place in varying degrees within the tree - plant - soil system (Mitchell *et al.*, 1975; Bormann *et al.*, 1977).

Switzer and Nelson (1972) reported that the nutrients taken up by trees are returned eventually to the soil. The principal agencies involved are throughfall, litter fall, stemflow, shedding of roots and exudation from roots.

2.2.1 Litter fall

Vinha and Pereira (1983) reported that the phenology of litter production in trees vary from species to species in wet tropical ecosystems. Das and Ramakrishnan (1985) reported that the litter on the forest floor acts as an input-output system for nutrients.

Happy Mathew (1993) reported that the litterfall from mango, jack, portia and coconut was 8.4, 11.2, 11.8 and 5.0 t ha^{-1} yr^{-1} respectively, from a coconut based homegarden in South Kerala.

Nair and Shrivastava (1985) compared the litter fall in plantations and natural stands and found that maximum litter measured was higher in the plantations than in the natural stands. Chaubey *et al.* (1988) reported that litter production was greater (1.5 - 2.0 t.ha^{-1}) in teak plantation than natural forests. Litter production from protected sites and unprotected sites also varied considerably. Nirmal Ram *et al.* (1986) observed that the annual litter production was 4885.7 kg ha^{-1} from the protected site and 3648.9 kg.ha^{-1} from the unprotected site. Shajikumar and Ashokan (1992) estimated the quantity of litter produced by *Eucalyptus terticornis*, *Glyricidia sepium*, *Leucaenea leucocephala* and *Ailanthus tryphysa* as 4059, 1751, 3323 and 1593 kg $.ha^{-1}.yr^{-1}$ respectively.

Westman (1978) studied the nutrient dynamics of litter in a subtropical eucalyptus forest and reported that litter fall was greater during summer.

The average annual litterfall in two coniferous forests were estimated as 5400 and 4380 kg. $ha^{-1}.yr^{-1}$ respectively (Cole and Rapp, 1980). The nutrient return of N, P and K was 61.0, 4.0, and 42.0 kg ha^{-1} yr^{-1} and 37.0, 4.0 and 26.0 kg ha^{-1} yr^{-1} respectively for temperate deciduous and for temperate coniferous forests.

Happy Mathew (1993) reported an annual addition of 8.495 kg, 2.0 kg and 6. 36 kg N, P and K respectively in a 0.2 ha homestead containing two each of mango and jack trees, three portia trees and twenty seven coconut palms.

In a study conducted by Nagaraja *et al.* (1996) in the southern dry regions of Karnataka under various systems, found that about 5 to 10 $t.ha^{-1}$ of biomass could be generated through mango, sapota and fodder trees. Vishwanath *et al.* (1996) reported that the shade trees like jack, champaka, goni, hemmaralu and erythrina commonly found in a cardamom plantation played a vital role in recycling of nutrients from the lower soil depth to the surface. Jack tree was found to contribute maximum biomass of 4.71 t. $ha^{-1} \cdot yr^{-1}$ through fallen leaves, compared to the least (0.97 t $ha^{-1}.yr^{-1}$) with hemmaralu.

Species variation in trees is an important factor in cycling of nutrients. Tappeiner and Alm (1975) reported that there was interspecific differences in leaf nutrient contents within the plant communities.

Season is another factor which determines nutrient return. According to Bray and Gorham (1964), moist tropical forests shed litter at a fairly steady rate through out the year, whereas, the deposition in arid-zone ecosystem is unpredictable because of the variation in the timing and magnitude of precipitation. Procter *et al.* (1985) reported that the nutrient status of the site was characterised by the total content in litterfall.

Site characteristic is another factor which determine the nutrient return. Thomas and Grigal (1976) and Chapin *et al.* (1980) found that species grown in infertile site showed greater proportional retranslocation of N, P and K, than the species adapted to fertile site.

Switzer and Nelson (1972) found that after 20 years of biomass and nutrient accumulation, the plant ecosystem drew very little of its annual nutrient requirement from soil reserve. Instead, it obtained most of its needs from the established external litter decay.

2.2.2 Throughfall and stemflow

The composition of throughfall and stemflow had been studied in a number of ecosystems, especially in western hemisphere and in Australia. Most of the reports were for temperate hard woods and conifers. Very little attention has been paid to study the nutrient cycling properties of the tropical species.

Halvey and Patric (1965) found that rain striking plant surfaces either drops to the soil as throughfall or is channelled to the ground as stemflow. In most situations 85 per cent or more of input was by throughfall and sometimes less than 10 per cent was by stemflow.

Miller *et al.* (1976) observed that throughfall accounted for about two-third of the gross rainfall, whereas, stemflow represented only from 1.7 to 34 per cent.

Harry *et al.* (1978) reported that stemflow accounted for only two per cent of the water received beneath the canopy and it was positively correlated with tree diameter. Charley and Richards (1983) reported that the annual nutrient load in throughfall varied greatly with tree species. They found that the nutrients in throughfall in tropical forests were greater.

George (1979) observed that throughfall water contained less elements when compared to stemflow. Baker and Attiwill (1987) found that the concentration of all elements were greatest in stemflow than in throughfall.

Happy Mathew *et al.* (1996) reported that the nutrient input through stemflow in a 0.2 ha homestead was 0.01, 0.00 and 0.01 kg yr^{-1} of N, P and K respectively, while the quantities added by throughfall was 2.10, 0.10 and 3.17 kg N, P and K respectively.

Manokaran (1980) observed that the addition of nutrients to the soil by way of throughfall and stemflow in a low land tropical rain forest was 6.7, 24.6, 3.9, 1.4 & 19.2 kg ha^{-1} yr^{-1} of N, K , Ca, Mg and Na respectively.

2.2.3 **Nutrient removal**

Khanna and Nair (1977) reported the output from leaves of a thirty year old coconut plantation was 33.1, 3.8 and 13.4 kg. $ha^{-1}.yr^{-1}$ of N, P and K respectively and 0.4, 0.1 and 0.3 kg. $ha^{-1}.yr^{-1}$ N, P and K respectively from the spathe and rachis.

Happy Mathew (1993) estimated the nutrient contents of harvested coconut leaves (550 kg biomass) for one year which amounted 3.972, 0.669 and 2.223 kg of N, P and K, respectively.

Venkitaswamy (1996) stated that coconut produced large quantities of waste materials such as leaves, spathes and stipules besides husks which were rich in various plant nutrients. He suggested that the recycling of these parts could add considerable quantities of organic matter to the field. Recycling of waste material could add nutrients to the tune of 25.0 $kg.ha^{-1}.yr^{-1}$ of N, P and K respectively.

Nagaraja *et al.* (1996) estimated that about 10.0 t. ha^{-1} of biomass could be generated through mango, sapota and fodder trees.

2.3 Soil properties

The homestead farming is very complex due to the involvement of a number of components including multipurpose tree species and animals. Due to the constant addition of the organic matter to the soil by litterfall, the chances of changes in soil physico-chemical properties is great (Brinson *et al.*, 1980).

According to Young (1986), the fundamental reason why agroforestry systems are perceived to improve soil properties is the protection that the tree cover gives to the soil, against surface compaction, run off and erosion.

2..3.1 Soil physical properties

Mazurak *et al.* (1975) reported significant reduction in bulk density of soil with application of farm yard manure and other manures due to more number of large aggregates. Morachan (1978) reported significant decrease in bulk density with increase of organic carbon content of the soil.

Nelliat and Shamabhat (1979) reported that mixed farming caused substantial improvements in the physical and biological characteristics of the soil.

Lal (1989) reported that lower soil bulk density, higher soil moisture retention and available plant water capacity under alley cropping practices compared to non alley cropping practices.

Nair (1993) found an enhancement of soil physical properties such as structure, porosity, moisture retention and erosion resistance under forest cover and trees due to addition of organic matter through the litter and root residues.

Pushkala and Sumam (1990) reported that the porosity and water holding capacity of the soil was more in plots planted with coconut, nutmeg and jack when compared to bare plots.

Happy Mathew *et al.* (1996) reported that the soil in the homestead had a lower bulk density, higher particle density, water holding capacity and moisture content when compared to the open control.

2.4 **Chemical properties**

According to Nair (1984), the gradual accumulation of mineral nutrients by perennial, slow growing trees and the incorporation of these into the enlarged plant-litter-soil nutrient cycle was the mechanism responsible for soil enrichment and improvement in soil chemical properties.

Swaminathan (1987) opined that the inclusion of multipurpose woody, leguminous trees and shrubs in low input farming systems reduce soil erosion and improve soil structure and fertility.

Lal (1989) reported that over a period of six years, the relative rate of decline in status of nitrogen, pH and exchangeable bases were much less under alley cropping than under continuous cropping without trees.

Happy Mathew *et al.* (1996) observed that the soil in the homestead have a higher organic matter content and available N, P and K contents as compared to the open control plot.

2.5 Micro-organisms

Due to the complex nature of homestead systems not much studies have been attempted on the rhizosphere micro-organisms in the system

Clark (1949) reported that the nature and activity of microflora and fauna in a given soil environment depend upon the crops grown and the management practices followed.

Nair (1973) observed that short term changes in soil environment produced by season and to a small extent by crop species brought about temporary quantitative changes in soil.

Bharadwaj and Gaur (1970) found that the *Azotobacter* population increased or decreased with organic matter in the soil. Potty (1977) reported that the number of fungi and actinomycetes were higher in rhizosphere of coconut palms, when the interspaces of palms were intercropped with fodder crops.

Kothandaraman *et al.* (1987 and 1990) opined that the counts of total bacteria, fungi and actinomycetes were higher in rubber plantations, cover cropped with *Mucuna bracteata*. They also found out that the counts of *Beijerinkia* and phosphate solubilising microrganisms were higher in legume cover cropped rubber plantations.

Happy Mathew (1993) observed that the counts of bacteria, fungi and actinomycetes were higher in the soils of a coconut-based home garden than that of an open control.

Prathapan (1995) observed that the soils of a legume cover cropped rubber plantation had a higher population of bacteria, fungi and P solubilising organisms and he opined that the reason for this was the increased biomass production and increased quantity of soil moisture in summer months.

2.6 Microclimate

The microclimate in a homestead system vary widely when compared with a pure crop system.

2.6.1 Soil temperature

Nair and Balakrishnan (1977) concluded that a crop cover on the ground helped to reduce temperature at the soil surface during summer months and the crop combination act as a buffer against drastic changes in ecoclimate.

Nair (1983 and 1984) observed that the homestead system caused less exposure of the bare soil and hence reduced soil temperature.

Happy Mathew *et al.* (1996) observed that the soil temperature in the homestead was always lower than the open control.

2.6.2. **Relative humidity**

Relative humidity is an important factor which influences crop yields indirectly by changes in the rates of evapotranspiration and by incidence of pests and diseases.

Nair and Balakrishnan (1977) reported that shading reduced air temperature in the crop combination and the higher relative humidity values caused considerable reduction in the rates of evaporation. They found that relative humidity in all cropping systems with coconuts had a higher value than open area.

Happy Mathew *et al.* (1996) reported that the relative humidity in homestead was always lower than that in open control.

2.7 Light intensity

Solar energy is one of the basic necessities for crop production. So the study of the light penetration by the tree canopies and their shading effect assumes importance in any cropping system.

Garner (1965) reported that solar radiation is the primary force for evapotranspiration.

Nelliat *et al.* (1974) studied the apparent coverage of ground by coconut palms of different age groups. They observed that when the palm is about 8-10 years of age, the percentage of light transmitted was only about 20 percent and then the transmission increased progressively and the canopy coverage of the ground decreased.

Nair and Balakrishnan (1976) measured the intensity of light falling at the plantation floors of coconut during different seasons of the years at different distances from the palms of about 25 years of age . They found that at a distance of 3.5 m from the base of the palms, the interception of solar radiation by coconut leaves was only 44 per cent of the radiation. They also reported that the percentage interception of available light by coconut palms was maximum during the early morning and therefore the peak availability of light for other intercrops was during 10.00 hrs to 16.00 hrs.

Nair (1979) observed that the leaf canopies of components in a typical homestead are arranged in such a way that they occupy different vertical layers with the tallest component having foliage tolerant to strong light and high evaporative demand and shorter components having foliage requiring or tolerating shade and high humidity.

Nair and Sreedharan (1986) reported that during the initial stages of coconut growth, all sun loving crops were grown in lower tier and from bearing stage (8 years) to about 25 years of coconut, when the shade was rather dense, shade loving crops like yams, turmeric, ginger and so on were grown. Afterwards the incoming solar radiation in the garden increased and the homestead could be filled with a number of annual and perennial crops .

2.8 Economic analysis

Economic analysis is important to ascertain whether the system is sustainable or not. The best way of economically analysing a homestead agroforestry system is by way of benefit:cost analysis and calculation of net return (Hoekstra, 1985).

Whenever input / output data are available, computation may be made to evaluate the proposed or existing system. The computational methods available for such evaluation are subdivided into optimization and non-optimization ones. While the first type enables the analyst to find the optimum solution, the second type enables the analyst to determine which of the alternative situation is the better one, not necessarily the optimum one. (Hoekstra, 1985).

The optimization methods are based on the technique of linear programming, which had been described by Beneke and Winterboer (1978)and Heady and Candler (1959).

Hoekstra (1985) observed that because of the rather large amount of data required over a long period, these optimization methods are not very popular for analysis of agroforestry systems. Hence, he suggested the non-optimization method, better known as benefit : cost ratio analysis as a better method for analysing agroforestry systems.

Leaf litter from trees and shrubs may be used to add soil nutrients and organic matter to the soil. So far there were no recorded instances of leaf litter being sold commercially. Market prices may be derived on the basis of nutrient content and prices of commercially available fertilizers (organic and inorganic). Hence leaf litter should be valued through the agricultural production system. This approach has been reported by Balasubramanian (1983) ; Hoekstra (1985) ; Ngambekii and Wilson (1984) and Vergara (1982).

The basic premise of an agroforestry system is that total benefit is greater where joint rather than singular production exists. Several authors have studied the use of joint production economics in analysing agroforestry systems. (Etherington and Mathews, 1983; Harou, 1983; Hoekstra, 1985 and Raintree, 1982).

Nair (1976) calculated the net income from a multistorey crop combination of coconut + black pepper + cocoa + pineapple in existing coconut garden of about 25 years of age in Kerala under irrigated management as Rs. 15,430/- per annum. Nelliat and Krishnaji (1978) reported a net return of Rs.15,661/- from a multistorey cropping system with black pepper, cocoa and pineapple in one hectare of coconut under rainfed condition in Kerala. They also estimated a net return of Rs. 11,631/- in a mixed cropping of one hectare of rainfed area with 50 per cent of area under coconut and the rest for tuber crops viz., cassava, elephant foot yam, sweet potato and greater yam.

Kandaswamy and Chinnaswamy (1988) found that among different mixed farming practices, dairy based system was most profitable with a mean annual net income of Rs. 6,090/- followed by dairy-cum-poultry based farming system having an annual net income of Rs. 5,899/-.

Abdul Salam and Sreekumar (1990) conducted a study in a 0.27 ha. sized homestead with coconut based mixed farming and found that the income generated from the home garden was sufficient to meet the home demands as well as the educational requirements of a seven member family consisting of five children. Besides 60 coconut palms, the system included arecanut, pepper, jack tamarind, mango, banana, tapioca, tuber crops, vegetables, fruit plants, guinea grass, glyricidia, a cow, ten chicken and five bee hives.

Abdul Salam *et al.* (1991) developed a homestead model with coconut based mixed farming system suited for coastal uplands of southern Kerala, which ensured a net return of Rs. 12,628/- with a benefit: cost ratio of 1.64.

Happy Mathew and Nair (1996) after an investigation in a homestead of 0.20 ha, estimated that the annual net return from the system was Rs. 29,115/-. The maximum net return was from poultry while the maximum benefit: cost ratio was for coconut cultivation. The overall benefit: cost ratio of the homestead was 1.6.

MATERIALS AND METHODS

MATERIALS AND METHODS

An experiment was undertaken to investigate the nutrient cycling, soil productivity and economic aspects of a homestead in Thiruvananthapuram district in the southern zone of Kerala. The study was conducted in a 0.48 ha. homestead for a period of one year from June 1994 to May 1995. The study envisaged, among other things, estimation of nutrient addition in the homestead by different tree species by litter fall, stemflow and through fall, the influence of trees on the physical, chemical and biological properties of the soil and the microclimate. The biomass production by different species of crops and the overall economics of the unit were also worked out. The materials used and the methods adopted for the study were as follows.

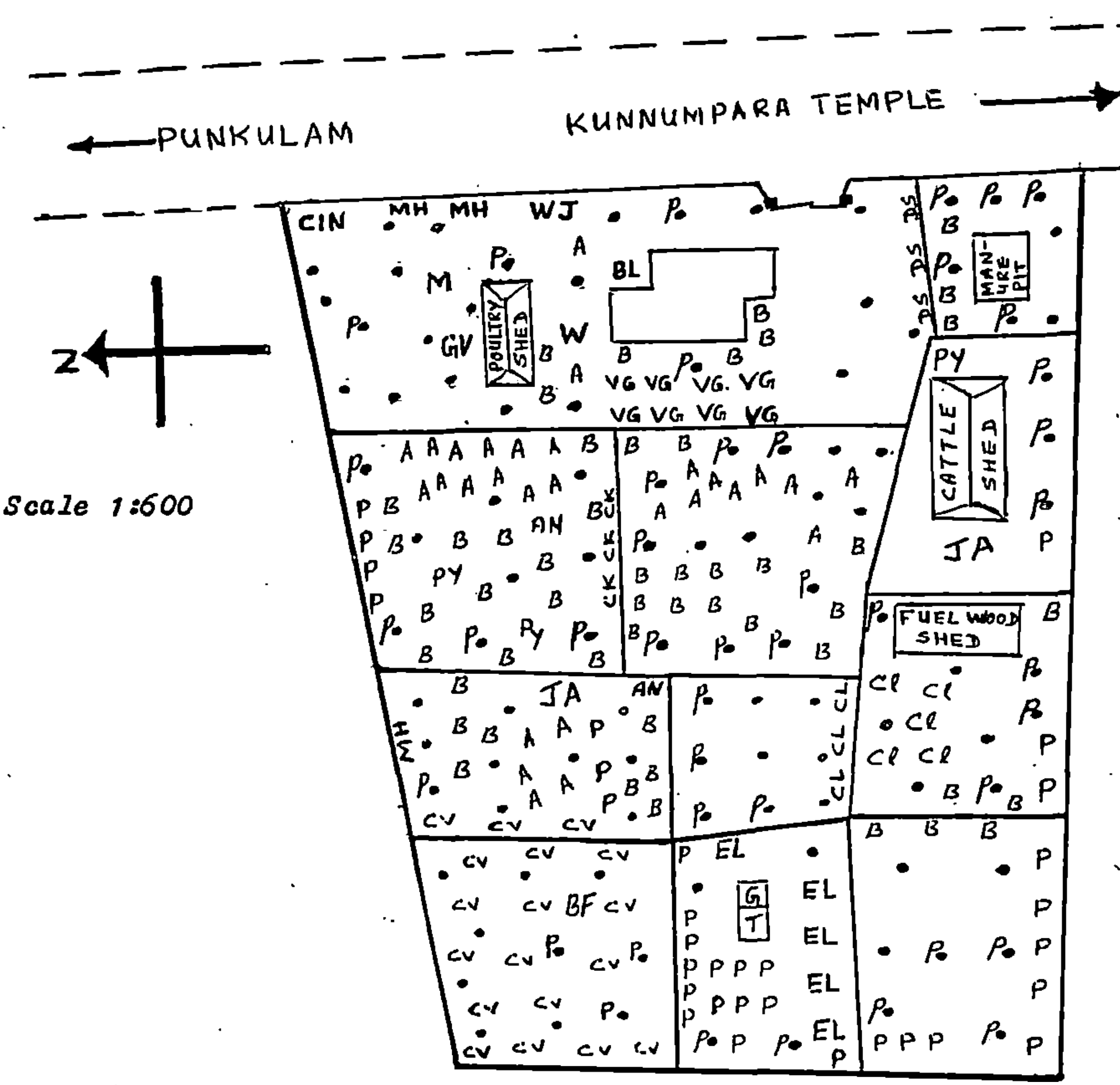
Location of the homestead

The homestead selected was situated on the western side of the Poonkulam - Kunnumpara temple road, about 0.5 km. away from Poonkulam and 1.5 km. away from the College of Agriculture, Vellayani, Thiruvananthapuram. The details of the homestead are given below.

Place	: Poonkulam
Panchayat	: Thiruvallam
District	: Thiruvananthapuram

Table 1 Components of the homestead under study

Sl.No	Enterprise	Population/area	Space used (m^2)
1	Adult coconut	96 nos.	4355
2	Young coconut	8 nos.	187
3	Banana(Palayankodan)	50 nos.	256
4	Tapioca	-	320
5	Amorphophallus	80 nos.	190
6	Coconut + pepper	42 nos.	59
7	Erythrina+ pepper	36 nos.	17
8	Colocasia	-	80
9	Ginger	-	38
10	Turmeric	-	35
11	Curry leaf	7 nos.	11
12	Chekurmanis	18 nos.	23
13	Drumstick	6 nos.	26
14	Bread fruit	1 no.	23
15	Jack	2 nos.	215
16	Mango	1 no.	22
17	Guava	1 no.	18
18	Papaya	3 nos.	12
19	Wild jack	1 no.	43
20	Cinnamon	1 no	17
21	Ailanthus	5 nos.	163
22	Mahogany	3 nos.	31
23	Rose apple	1 no.	11
24	Vegetables	-	160
25	Annona	2 nos.	53
26	Bilimbi	1 no.	34
27	Cow + calf	2 nos.	23
28	Goat + kids	4 nos.	15
29	Poultry	23 birds	22
30	House & permanent structures	-	222
	Total		6681



•	Coconut	GV	Guava	G	Ginger
P•	Coconut + Pepper	EL	Ailanthus	T	Turmeric
P	Erythreca + Pepper	VG	Vegetables	DS	Drumstick
B	Banana	BL	Bilimbi	CL	Curry leaf
JA	Jack	MH	Mahogany	CK	Chekurmanis
A	Amorphophallus	WJ	Wildjack	Cl	Colocasia
CV	Cassava	CIN	Cinnamon	AN	Annona
BF	Bread fruit	P	Papaya	M	Mango

Fig. 1 Plan of homestead showing the position of different crops

State	: Kerala
Latitude	: 8.5 ^{0} N
Longitutde	: 76. 9 ^{0} E
Elevation	: 29 m. above MSL
Area of the home garden	: 4840.00 m ^{2}. (0.484 ha)
Soil type	: Red loam.

Mechanical composition of the soil

Coarse sand	- 64.0%
Fine sand	- 11.3%
Silt	- 13.9%
Clay	- 9.5%

3.1 Description of the selected homestead

3.1.1 Species composition and density

The detailed inventory of the homestead showing the different components such as crops, permanent structures like house, well, poultry shed, cattle shed, goat houses and the space used by each component is presented in the Table 1. & Fig.1.

3.2. Nutrient cycling

3.2.1. Litterfall

3.2.1.1.Method of litter collection

Litter collection from jack, ailanthus, mango, wild jack, guava, cinnamon, mahogany, bilimbi and annona was undertaken with litter

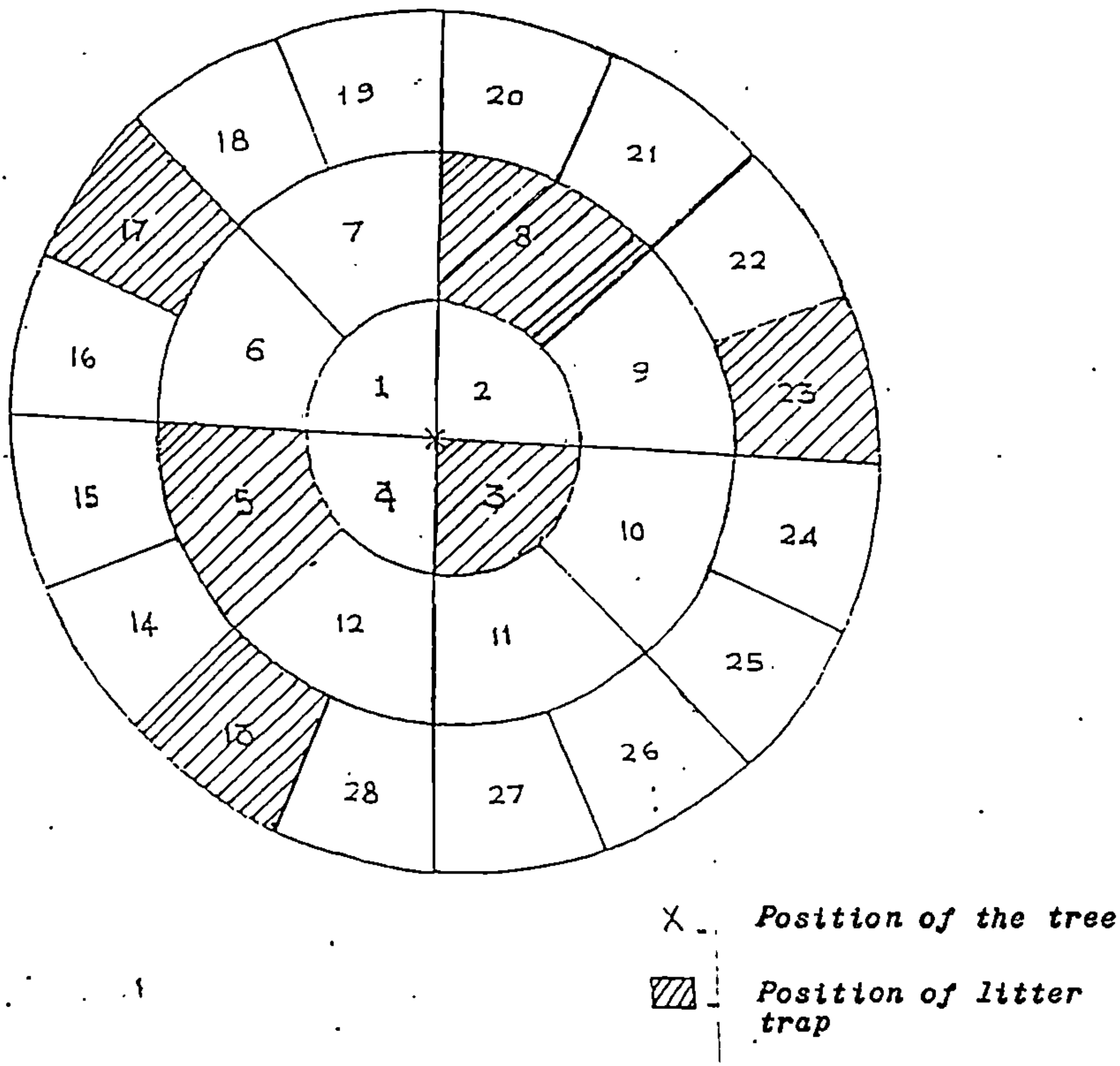


Fig. 2 Schematic representation of positioning of litter traps

traps devised by Happy Mathew (1993). Bamboo baskets of 50 cm diameter and depth of 30 cm were used to receive the falling litter. These baskets were set below the trees on tripods of wooden poles at a height of 50 cm from the ground to prevent the entry of soil into the baskets during splashing of rain water. The canopy area of each tree was demarcated on the ground . This was then divided into 28 semi circles (Fig.2). Six traps were set in the semicircles at random. In the case of large trees, number of traps were increased so that the gross reception area of the baskets was not less than 10 per cent of the canopy area of the tree . The position of the traps were interchanged at quarterly interval by adopting a set of fresh random numbers. The change in position would account for the spatial variation encountered beneath the canopy. The damaged baskets were removed and replaced with fresh ones.

In the case of coconut, the data on leaves that fell off naturally and that harvested from the trees were taken and this was accounted for, while calculating the biomass production and nutrient removal from the homestead.

3.2.1.2. Chemical analysis of the litter

The litter samples from the tree species were collected at fortnightly interval and these samples were dried at 70^0C in a hot air oven. The samples collected from each tree were separated. The samples were pooled species-wise and analysed for their nitrogen, phosphorus and potassium contents. The methodology adopted for nutrient analysis are given below:

Nitrogen	-	Microkjeldahl method (Jackson, 1973)
Phosphorus	-	Vanadomolybdate phosphoric yellow method (Jackson, 1973)
Potassium	-	Flame photometry (Jackson, 1973)

3 .2.1.3 **Quantification of litter and nutrient addition**

From the data on dry weight of litter collected at fortnightly interval, the quantity of dry litter per month was calculated. From this, the litter fall per unit area of the tree canopy on oven dry basis was found out. The quantification was done separately for each tree species in the homestead using the following formula.

$$\text{Annual litterfall } (kg.yr^{-1}) = \sum_{i=1}^{12} \frac{\text{Monthly dry litter collection in the litter trap (kg)}}{\text{Area of the litter trap } (m^2)} \times \text{Canopy area } (m^2)$$

where, ' i ' represents the number of months in the crop year, its value ranging from 1 to 12.

From the total quantity of litter and its nutrient content, the nutrient addition by litterfall to the whole system was estimated and expressed in $kg.yr^{-1}$.

3.2.2. Throughfall

3.2.2.1. Method of collection of throughfall

Throughfall was collected with the help of a locally fabricated device consisting of a funnel of 8.0 cm diameter inserted into the neck of a 750 ml bottle. These devices were placed under the canopy of each tree at the rate of one device for each 5 m^2 of the canopy area. The litter and other materials which fell inside the gauges were trapped by plugs of sterilised cotton, which were replaced at periodical interval. These gauges were placed randomly.

To account for the spatial variation encountered beneath the tree canopy, the location of the traps under each tree was changed at monthly interval. A similar gauge was set up in an open area outside the homestead along with a standard raingauge. The water collected in the gauge was measured at periodic interval, depending on the volume of water collected in the gauges during the rains.

3.2.2.2. Chemical analysis of throughfall

Throughfall samples collected during the rainy season were stored at 2^0C awaiting analysis. The nutrients were estimated at monthly interval after pooling the samples, collected from each tree (Miller *et al.*, 1976). Similar samples were collected from open area and analysed.

3.3.2.3. Nutrient addition by throughfall

It was assumed that all the water coming by way of rainfall over the tree canopy is channelled to the ground as throughfall and stemflow . The total quantity of water by rainfall was calculated from the readings of automatic raingauge. The total quantity of throughfall was calculated from the canopy area, stem flow volume and the total quantity of rainfall received over the area.

$$\text{Total volume of water received by rainfall over the canopy area (l)} = \frac{\text{Volume of water received for unit rain (l)} \times \text{Total rainfall} \times \text{Canopy area } (m^2)}{\text{Area of the gauge } (m^2)}$$

$$\text{Vol. of water by throughfall in a tree (l/tree)} = \text{Total vol. of water recorded by rainfall (l/tree)} - \text{Vol. of water collected by stemflow from the same tree (l/tree)}$$

From the volume of throughfall and its nutrient content, the total nutrient addition by each tree for each month was calculated.

3.2.3. Stemflow

3.2.3.1. Method of collection of stemflow

A device was fabricated locally to direct all the water flowing through the main stem of the respective tree species into a collecting vessel. The device consists of a medium sized tapping shade fixed firmly around the main stem with the help of coal tar. The joints were further sealed water proof by pasting coaltar along the joints. The peripheral flaps of the tapping shade was folded upwards so that all the water falling into it, is diverted to the collecting portion of the tapping shade, which is inserted into a funnel of 30 cm diameter, which in turn was inserted into a 35 litre jerry can placed on the ground.

The coaltar, which is used to seal the joints was washed thoroughly with water, a number of times, to ensure that, it was free of the plant nutrients.

3.2.3.2.**Nutrient addition by stemflow**

The volume of water received by stemflow from each tree species was measured at periodic intervals depending upon the intensity and duration of rainfall. The total quantity of water received by stemflow was thus computed for each tree at monthly intervals. From this, the nutrient contents in the stemflow and the total nutrient addition by each tree species at monthly intervals to the homestead by stemflow was calculated. The estimates were converted for the whole system and expresssed in kg yr^{-1}.

3.2.4. **Nutrient addition by livestock and poultry**

The quantity of dung excreted by cow and sheep were recorded.

The total amount of manures added to the homestead were quantified. The poultry litter added was also recorded.

3.3. Nutrient removal from the system

The total quantity of nutrients removed from the homestead by harvested produce was calculated by multiplying the biomass produced by a particualar crop / tree with its respective nutrient content. The methodology used for analysing the produce for its nutrient contents is similar to that used in the case of leaf litter.

3.4. Soil properties

Soil samples were collected from the homestead at 15 cm and 30 cm depth at half yearly intervals. A number of composite samples were collected from different parts of the field for analysis. The nutrient status of the soil before the start of the experiment was also estimated. The soil properties studied and the analytical methods adopted for their estimation are given below.

3.4.1 Physical properties

(a) Mechanical analysis (%)	- International Pipette Method (Piper, 1966)
(b) Particle density ($g. cc^{-1}$)	- Keen - Raczkowski box method
(c) Bulk density ($g.cc^{-1}$)	- Keen - Raczkowski box method

(d) Maximum water holding capacity - Keen - Raczkowski box method

(e) Moisture content (%) - Oven dry method

3.4.2 Chemical properties

(a) Available nitrogen (%) - Alkaline permanganate method (Subbaih and Asija, 1956)

(b) Available phosphorous (%) - Bray colorimetric method (Jackson, 1973)

(c) Available potassium (%) - Flame Photometer method (Jackson, 1973)

(d) Organic carbon (%) - Walkley and Black rapid titration method (Jackson, 1973)

(e) Soil pH - pH meter method (Jackson, 1973)

3.4.3 Microbial properties

Soil samples were collected from ten fixed spots in the rhizosphere of different crop species of the homestead, at six month intervals. These samples were pooled and analyzed for microbial population within 24 hrs. of collection. The total number of bacteria, fungi, actinomycetes and P solubilising bacteria per gram of soil was estimated by dilution plate technique (Timonin, 1940). Bacteria was estimated at 10^{-8} dilution, phosphate solubilising bacteria and actinomycetes at 10^{-6} dilution and the fungi at 10^{-4} dilution. Soil samples collected from control fields were also analysed for micro-organisms.

Kauster medium (Subba Rao, 1973) was used for growing bacteria, Kenknight and Munaier's medium (Subba Rao, 1973) for actinomycetes, Pikovskaya's (Modified by Sundara Rao and Sinha, 1963) medium for phosphate solubilising bacteria and Martins Rose Bengal Agar medium (Subba Rao, 1973) for fungi. The bacterial, fungal, actinomycetes and P solubilising bacteria colonies were developed after 2, 4, 6 and 7 days respectively. The readings were recorded as colony forming units (c.f.u).

3.5 **Microclimate**

A field observatory was set up in the homestead to observe the maximum and minimum atmospheric temperature, soil temperature, light intensity, and relative humidity both in homestead and in the open area (control). An automatic rain gauge was also fixed in an open space of the homestead to record the rainfall data.

3.5.1 **Soil temperature**

Soil thermometers were installed at four locations in the homestead at a depth of 15 cm and 30 cm. One set was maintained in the open control. Observation of soil temperature was taken at 7.25 am and 2.25 pm every day and monthly mean for each depth calculated.

3.5.2 Relative humidity

The relative humidity in the homestead and in the open field was recorded at a height of 1.5 m. from the ground using a dial psychrometer. The relative humiditiy below the major perennial trees in the homestead viz., coconut, jack, ailanthus, mahogany, mango and wild jack was observed and compared with that in the open field. The measurements were made at fortnightly intervals.

3.6 Light intensity

The shading effects of the tree species (coconut, ailanthus, jack and mahogany) in the homestead and their light interception during different times of day were studied at monthly interval. The light intensity was determined under these trees in the ground level at a distance of 2 m from the tree base using a lux meter. The data were collected at 12.00 noon. The light intensity in the open area was also measured at the same time and interval. From the data, the percentage interception of solar radiation, the light penetration characteristics and the shading effect of the tree crops were calculated.

3.8. Economic analysis

The economics of the whole system was worked out. All enterprises/ activities in the homestead were spatially defined and their total costs, gross return and net return were found out. From the space utilised by the crops, the cropping intensity was worked out. From the total costs incurred in the system and the gross return, the benefit: cost ratio was calculated. The method adopted for evaluating the homestead was the non-optimization method, which is also known as cost benefit analysis (Hoekstra, 1985).

RESULTS

RESULTS

A field experiment was conducted in the homestead at Punkulam,in Thiruvananthapuram districtt of Kerala State, for a period of one year from 1st June, 1994 onwards. An inventory of the homestead was undertaken and different components and agronomic resources of the homestead were identified. The yield, including the boimass from different crops in the homestead was recorded and quantification of nutrients added through litterfall, throughfall and stemflow of the major tree components were also undertaken. A field laboratory was established and observations were taken to monitor the changes in the microclimate in the homestead. To assess the profitability of the homestead, the inputs and outputs of the system were transformed into monitory form and the economics of the homestead was worked out on the benefit:cost ratio basis. The results of the study are presented hereunder.

4.1. Structure and function of homestead

The components of the selected home garden, which had an area of 0.48 ha, are listed in Table 1.

The topography of the homestead was undulating. Earthern bunds were constructed across the slope to conserve soil and water. The soil type was red loam and the initial nutrient status of the soil was 342.8 kg ha^{-1} N, 57.9 kg ha^{-1} P and 303.0 8 kg ha^{-1} K.

A detailed inventory of the components in the homestead was taken (Table 1) and the space occupied by each component was found out. The area occupied by the permanent structures like house, well, cattle shed, goat house, poultry shed and fire wood shed was estimated.

The irrigation source of the selected homestead was a well. A 0.5 HP pumpset, established near the well, was used for pumping out water for domestic purposes and for irrigation.

4.1.1 Farm family

The selected homestead was inherited by Smt. Naliniamma from her parents. She has one daughter and two sons. The daughter along with her husband and two children are staying with her and they are looking after the day-to-day activities of the homestead. Her elder son is employed abroad and younger son is employed outside the district. The family employed two servants for carrying out the domestic and farming activities of the homestead.

4.1.2 Crops and cropping pattern

From the inventory (Table 1) it is evident that the selected homestead is a coconut- based system.

There were 96 adult coconut palms, spaced uniformly throughout the homestead. Apart from this, eight non-bearing young coconut palms were also planted in the homestead. In the interspaces of the coconut palms, different crops were grown without any specific planting pattern. Fifty banana (var. Palayankodan) plants were grown in the homestead, which occupied about 256 m^2 area of the homestead. Tapioca was grown in 320 m^2 area, and amorphophallus which numbered 80, occupied 190 m^2 in the interspaces of coconut. Pepper was trailed on coconut (42) and erythrina (36) standards.

Tree species of the homestead included two jacks (canopy area 215 m^2) and five ailanthus trees (canopy area 163 m^2). Jack was grown for fruits and timber purpose. Ailanthus tree was grown for green manure and also for soft wood. Three mahogany trees were maintained for timber purpose, the canopy of which were pruned heavily to promote main stem growth and to prevent over shading in the garden. The pruned leaves were also used as green manure. Mahogany occupied a gross area of 31 m^2 in the homestead. Another timber yielding tree grown in the homestead was wild jack which occupied 43 m^2 area.

Other fruit trees present in the homestead were mango, guava, bilimbi, breadfruit, rose apple and annona. These trees occupied an area of 161 m^2 in the home garden.

Ginger and turmeric were grown in an area of 73 m^2 in the homegarden, mainly to meet the household needs and the balance was sold to neighbours. Vegetables like bittergourd, ash gourd, tomato, brinjal, amaranthus and cowpea were raised in the home garden in an area of 160 m^2 mainly to meet the home needs.

The farmer possessed one Swiss brown milch cow and its calf. The five-year old milch cow had an average daily production of 3.5 litres of milk. The family consumption of milk was 2.5 litres per day and the balance was sold at a price of Rs. 8/- per litre. The farm family had also maintained two goats with their kids. The goats yielded an average of 0.4 litres of milk per day which was fully consumed by the farm family, in addition to the cow's milk. These animals were fed with green grass grown in the homestead, paddy straw, concentrates and other home wastes.

The farm family also maintained 23 poultry birds of local breed. They produced 1594 eggs for one year during the period of study.

The entire quantity of organic manures produced by different sources was applied in the homestead itself and the farmer was not using any inorganic fertilizers for cultivation of various crops.

The farmer resorted to only need based application of plant protection chemicals as and when the pest or disease incidence was severe.

4.1.3 Marketing

The surplus produce obtained after consumption was regularly marketed for income. The produces marketed were normally coconut (both nuts and leaves), banana, cassava, amorphophallus, pepper, vegetables, jack, papaya, rose apple, bilimbi fruits, milk and eggs.

Major portion of the agricultural income was from coconut. Both nuts and leaves were sold to merchants. Apart from this, the oil required for home consumption was extracted from copra and surplus coconut was sold to local market periodically. Other surplus produces were also sold locally except pepper which was sold at Nedumangad market, which is considered as a major market for spices.

4.2. Nutrient cycling

The data on litterfall from two jack trees during the period of study are presented in Table 2. The total quantity of dry litter produced during the period was 138.41 kg. Seasonal variation in the litter production was observed with the maximum quantity during

January, 1995 (18.62 kg) and the minimum during April, 1995 (0.31 kg). N, P and K contents of the litter varied from 0.9954 to 1.3782, 0.2700 to 0.2950 and 0.3850 to 0.4560 per cent respectively. Total quantity of N, P and K cycled back through litterfall into the homestead from jack trees during the period of study was 1.4680, 0.3906 and 0.5606 kg respectively.

A total dry matter of 99.77 kg was produced from the litterfall of the five ailanthus trees which had a gross canopy area of 163 m^2 (Table 3). Nutrient contents in the dry litter of ailanthus varied from 1.0018 to 1.3956, 0.2700 to 0.3450 and 1.0150 to 1.8350 per cent of N, P and K respectively. Thus, 1.2202 kg N, 0.3026 kg P and 1.4393 kg K were returned to the soil through litterfall from five ailanthus trees. The maximum litter production of 13.09 kg was during January 1995 and the minimum (5.0 kg) during May 1995.

From a gross canopy area of 31 m^2 of three mahogany trees, 16.71 kg litter was added to the soil during the course of the study (Table 4). Maximum litter production (1.93 kg) was during January 1995 and the minimum (1.02 kg) during May 1995. The nutrient concentration of N varied from 0.9677 to 1.4185 per cent, P varied from 0.1800 to 0.2350 per cent and K varied from 0.5550 to 0.6950 per cent. Total nutrient addition by litterfall of three mahogany trees were 0.1902 kg N, 0.0308 kg P and 0.1015 kg K.

Table. 2 Total litterfall and nutrient addition by Jack during the period from June 1994 to May 1995

Month	Litter fall (kg)	Nutrient content (%)			Nutrient addition (kg)		
		N	P	K	N	P	K
June 1994	7.99	1.2103	0.2950	0.4090	0.0967	0.0236	0.0326
July 1994	11.83	1.0793	0.2800	0.3970	0.1277	0.0331	0.0470
August 1994	11.17	1.0029	0.2900	0.3850	0.1120	0.0324	0.0430
September 1994	11.61	1.1937	0.3050	0.4135	0.1386	0.0354	0.0480
October 1994	9.75	1.0754	0.2700	0.4210	0.1049	0.0263	0.0409
November 1994	9.41	0.9978	0.2950	0.4140	0.0938	0.0278	0.0390
December 1994	13.69	0.9954	0.2750	0.3950	0.1363	0.0376	0.0541
January 1995	18.62	1.0024	0.2700	0.3920	0.1866	0.0502	0.0729
February 1995	15.22	0.9985	0.2850	0.3975	0.1520	0.0434	0.0605
March 1995	12.70	0.9378	0.2750	0.3890	0.1181	0.0349	0.0494
April 1995	0.31	1.1137	0.2750	0.4380	0.1036	0.0256	0.0408
May 1995	7.11	1.3782	0.2850	0.4560	0.0980	0.0203	0.0324
Total	138.41				1.4670	0.3906	0.5606

Canopy area of jack : 215.00 m^2
Number of trees : 2

Table. 3 Total litterfall and nutrient addition by ailanthus during the period from June 1994 to May 1995

Month	Litter fall (kg)	Nutrient content (%)			Nutrient addition (kg)		
		N	P	K	N	P	K
June 1994	7.10	1.3956	0.2950	1.8350	0.0988	0.0209	0.1303
July 1994	8.31	1.2560	0.3150	1.7550	0.1044	0.0262	0.1458
August 1994	7.85	1.1092	0.3250	1.3500	0.0871	0.0255	0.1060
September 1994	8.16	1.1673	0.3300	1.3250	0.0952	0.0269	0.1081
October 1994	6.85	1.1101	0.3450	1.1250	0.0760	0.0236	0.0771
November 1994	6.62	1.0018	0.3150	1.1250	0.0663	0.0207	0.0745
December 1994	9.62	1.0780	0.2950	1.0150	0.1370	0.0284	0.0976
January 1995	13.09	1.3057	0.2800	1.4000	0.1709	0.0367	0.1833
February 1995	10.71	1.0356	0.2800	1.3550	0.1109	0.0300	0.1451
March 1995	8.93	1.1150	0.2700	1.6530	0.0996	0.0241	0.1476
April 1995	7.62	1.3877	0.3100	1.7250	0.1057	0.0236	0.1314
May 1995	5.00	1.3652	0.3200	1.8350	0.0683	0.160	0.0925
Total	99.77				1.2202	0.3026	1.4393

Canopy area of ailanthus : 163 m^2
Number of trees : 5

Table. 4 Total litterfall and nutrient addition by mahogany during the period from June 1994 to May 1995

Month	Litter fall (kg)	Nutrient content (%)			Nutrient addition (kg)		
		N	P	K	N	P	K
June 1994	1.05	1.1693	0.1950	0.6250	0.0123	0.0020	0.0065
July 1994	1.49	1.4185	0.2350	0.5900	0.0211	0.0035	0.0087
August 1994	1.27	1.2441	0.1850	0.6950	0.0158	0.0023	0.0088
September 1994	1.40	1.0525	0.2100	0.5550	0.0156	0.0029	0.0077
October 1994	1.33	1.1120	0.2250	0.6150	0.0149	0.0025	0.0088
November 1994	1.33	1.0073	0.2050	0.6050	0.0134	0.0027	0.0080
December 1994	1.54	0.9975	0.1900	0.5850	0.0154	0.0029	0.0090
January 1995	1.93	0.9677	0.1800	0.5700	0.0185	0.0034	0.0111
February 1995	1.82	1.1003	0.1800	0.5900	0.0200	0.0032	0.0107
March 1995	1.40	1.1323	0.2050	0.6750	0.0158	0.0028	0.0088
April 1995	1.13	1.3285	0.2200	0.6300	0.0150	0.0024	0.0071
May 1995	1.02	1.2163	0.2150	0.6250	0.0124	0.0002	0.0063
Total	16.71				0.1902	0.0308	0.1015

Canopy area of mahogany : 31.00 m^2
Number of trees : 3

Wild jack, covering an area of 43 m^2, added 33.43 kg of litter to the soil during the period of study (Table 5). Litter production was maximum during January 1995 (4.89 kg) and the minimum during June 1994 (1.13 kg). Nutrient content of the litter varied from 0.9810 to 1.4865 per cent, 0.3600 to 0.4250 per cent and 0.6350 to 0.9550 per cent in the case of N, P and K respectively. The wild jack tree contributed 0.3772 kg N, 0.1270 kg P and 0.2960 kg K to the soil during the period of study.

From a canopy area of 34 m^2, a litter quantity of 28.34 kg was obtained from bilimbi (Table 6). Seasonal variation in the litter production showed that the maximum production was during January 1995 (5.25 kg) and the minimum (0.68 kg) during March 1995. Variation in the nutrient contents in the litter ranged from 1.1000 to 1.8065 per cent, 0.1000 to 0.4550 per cent and 0.4800 to 0.5530 per cent in the case of N, P and K respectively. Total nutrient addition by bilimbi during the period was 0.3542 kg N, 0.1121 kg P and 0.1423 kg K to the home garden through litterfall.

Gross canopy area of the two annona trees was 53 m^2 and the litter production was 23.87 kg (Table 7) during the period of study. The maximum litter production of 4.66 kg was during January 1995 and the minimum of 0.16 kg, during the month of March 1995. The nutrient contents of the litter varied from 0.9675 to 1.2132 per cent, 0.2400 to 0.2900 per cent and 0.3850 to 0.4790 per cent of N, P and

Table. 5 Total litterfall and nutrient addition by wild jack during the period June 1994 to May 1995

Month	Litter fall (kg)	Nutrient content (%)			Nutrient addition (kg)		
		N	P	K	N	P	K
June 1994	1.13	1.2441	0.3850	0.8500	0.0141	0.0044	0.0096
July 1994	2.00	1.4865	0.3900	0.9350	0.0296	0.0078	0.0186
August 1994	1.84	1.3260	0.4250	0.8350	0.0244	0.0078	0.0154
September 1994	3.22	1.1125	0.4100	0.9150	0.0361	0.0132	0.0296
October 1994	2.50	1.1320	0.3950	0.9050	0.0282	0.0098	0.0226
November 1994	3.09	1.0937	0.3950	0.9050	0.0338	0.0122	0.0280
December 1994	4.02	0.9875	0.3600	0.9300	0.0397	0.0144	0.0374
January 1995	4.89	0.9810	0.3750	0.9450	0.0480	0.0183	0.0462
February 1995	4.60	1.1317	0.3600	0.9550	0.0521	0.0165	0.0439
March 1995	2.67	1.2113	0.3600	0.8350	0.0323	0.0096	0.0222
April 1995	2.00	1.1100	0.3750	0.6350	0.0222	0.0075	0.0127
May 1995	1.47	1.1375	0.3750	0.6650	0.0167	0.0055	0.0095
Total	33.43				0.3772	0.1270	0.2960

Canopy area of wild jack : 43.00 m^2
Number of trees : 1

Table. 6 Total litterfall and nutrient addition by bilimbi during the period of study from June 1994 to May 1995

Month	Litter fall (kg)	Nutrient content (%)			Nutrient addition (kg)		
		N	P	K	N	P	K
June 1994	2.81	1.4753	0.3900	0.5390	0.0415	0.0109	0.0148
July 1994	3.23	1.8065	0.4550	0.4950	0.0583	0.0146	0.0159
August 1994	1.94	1.3085	0.1000	0.5100	0.0254	0.0079	0.0098
September 1994	2.09	1.1837	0.3900	0.5250	0.0247	0.0081	0.0109
October 1994	0.98	1.1030	0.3750	0.5530	0.0108	0.0036	0.0054
November 1994	1.37	1.1175	0.4200	0.5300	0.0153	0.0057	0.0072
December 1994	4.78	1.1070	0.3900	0.5010	0.0523	0.0184	0.0236
January 1995	5.25	1.1000	0.3750	0.4800	0.0578	0.0196	0.0252
February 1995	1.29	1.1239	0.3950	0.4810	0.0145	0.0059	0.0062
March 1995	0.68	1.1030	0.4050	0.4930	0.0075	0.0027	0.0034
April 1995	1.80	1.1352	0.3900	0.5010	0.0204	0.0070	0.0090
May 1995	2.12	1.2137	0.3650	0.5170	0.0257	0.0077	0.0109
Total	28.34				0.3542	0.1121	0.1423

Canopy area of bilimbi : 34.21 m^2
Number of trees : 1

Table. 7 Total litterfall and nutrient addition by annona during the period of study from June 1994 to May 1995

Month	Litter fall (kg)	Nutrient content (%)			Nutrient addition (kg)		
		N	P	K	N	P	K
June 1994	1.40	1.1006	0.2400	0.3850	0.0154	0.0033	0.0053
July 1994	2.31	1.2115	0.2550	0.4500	0.0279	0.0058	0.0103
August 1994	2.56	1.0017	0.2750	0.4550	0.0256	0.0007	0.0116
September 1994	3.26	1.0010	0.2600	0.4250	0.0326	0.0084	0.0138
October 1994	3.07	1.1127	0.2750	0.3950	0.0341	0.0084	0.0121
November 1994	2.48	1.0010	0.2600	0.4010	0.0248	0.0064	0.0101
December 1994	2.29	0.9870	0.2550	0.4350	0.0226	0.0058	0.0100
January 1995	4.66	0.9675	0.2400	0.4750	0.0450	0.0111	0.0221
February 1995	0.64	0.9970	0.2500	0.4790	0.0063	0.0016	0.0031
March 1995	0.16	0.9986	0.2950	0.4350	0.0016	0.0005	0.0007
April 1995	0.32	1.1107	0.2750	0.4100	0.0035	0.0009	0.0013
May 1995	0.72	1.2132	0.2900	0.4050	0.0087	0.0021	0.0029
Total	23.87				0.2481	0.0550	0.1033

Canopy area of annona : 53 m^2
Number of trees : 2

K, respectively. During the period under study 0.2481 kg N, 0.0550 kg P and 0.1033 kg K were cycled back to the homestead through the litter in the case of annona.

Mango, with a canopy area of 22.0 m^2 produced 9.69 kg of dry litter (Table 8). Maximum quantity (1.26 kg) of litter was found to be produced during August 1994 and the least (0.36 kg) during April 1995. The contents of major nutrients in the litter varied from 0.9885 to 1.3125 per cent, 0.230 to 0.285 per cent and 0.575 to 0.650 per cent of N, P and K, respectively. So during the year, litter fall from mango resulted in a total addition of 0.1063 kg N, 0.0250 kg P and 0.1328 kg K.

The canopy area of guava tree was 18.0 m^2 and it had produced 7.39 kg of litter during the period of study in an ovendry basis (Table 9). Highest litter production of 0.97 kg was obtained during September 1994 and the lowest quantity of 0.31 kg was noticed during May 1995. The nutrient contents varied from 0.9652 to 1.3137 per cent, 0.31 to 0.42 per cent and 0.32 to 0.815 per cent of N, P and K, respectively. So during the period under study litterfall from guava contributed 0.0798 kg N, 0.0254 kg P and 0.0454 kg K to the soil.

Cinnamon with a canopy area of 17.0 m^2 produced the maximum quantity of 0.71 kg litter during September 1994 and the least quantity of 0.38 kg during the month of June 1994 (Table 10). The

Table. 8 Total litterfall and nutrient addition by mango during the study from June 1994 to May 1995

Month	Litter fall (kg)	Nutrient content (%)			Nutrient addition (kg)		
		N	P	K	N	P	K
June 1994	0.69	1.1483	0.2650	0.6300	0.0115	0.0018	0.0043
July 1994	0.98	1.1563	0.2500	0.6150	0.0113	0.0024	0.0060
August 1994	1.26	1.1013	0.2400	0.6500	0.0139	0.0030	0.0819
September 1994	1.00	1.1125	0.2350	0.6300	0.0113	0.0023	0.0063
October 1994	0.78	1.0075	0.2650	0.0610	0.0079	0.0020	0.0047
November 1994	0.84	0.9973	0.2750	0.5750	0.0061	0.0026	0.0048
December 1994	0.95	0.9885	0.2800	0.5800	0.0094	0.0026	0.0055
January 1995	1.12	0.9990	0.2600	0.5900	0.0111	0.0029	0.0066
February 1995	0.82	1.0073	0.2300	0.6250	0.0083	0.0018	0.0050
March 1995	0.50	1.2315	0.2500	0.6150	0.0062	0.0012	0.0030
April 1995	0.36	1.3125	0.2850	0.6400	0.0047	0.0010	0.0023
May 1995	0.39	1.1673	0.2750	0.6200	0.0046	0.0010	0.0024
Total	9.69				0.1063	0.0250	0.1328

Canopy area of mahogany : 22.0 m^2
Number of trees : 1

Table. 9 Total litterfall and nutrient addition by guava during the period from June 1994 to May 1995

Month	Litter fall (kg)	Nutrient content (%)			Nutrient addition (kg)		
		N	P	K	N	P	K
June 1994	0.45	1.2654	0.3600	0.7350	0.0057	0.0016	0.0030
July 1994	0.63	1.0135	0.3550	0.4600	0.0064	0.0022	0.0028
August 1994	0.57	1.1235	0.3750	0.5100	0.0064	0.0021	0.0029
September 1994	0.97	0.9800	0.3250	0.8150	0.0096	0.0031	0.0079
October 1994	0.61	1.0013	0.3200	0.3200	0.0061	0.0019	0.0019
November 1994	0.57	0.9837	0.3750	0.5600	0.0056	0.0021	0.0031
December 1994	0.84	0.9652	0.3600	0.6300	0.0081	0.0030	0.0052
January 1995	0.86	0.9758	0.3250	0.7100	0.0084	0.0027	0.0061
February 1995	0.80	1.3137	0.3100	0.6750	0.0105	0.0024	0.0054
March 1995	0.41	1.1256	0.4050	0.6600	0.0046	0.0016	0.0027
April 1995	0.37	1.2135	0.4200	0.6400	0.0045	0.0015	0.0023
May 1995	0.31	1.2553	0.4100	0.6800	0.0039	0.0012	0.0021
Total	7.39				0.0798	0.0254	0.0454

Canopy area of guava: 18.00 m^2
Number of trees : 1

Table. 10 Total litterfall and nutrient addition by cinnamon during the period from June 1994 to May 1995

Month	Litter fall (kg)	Nutrient content (%)			Nutrient addition (kg)		
		N	P	K	N	P	K
June 1994	0.38	1.4825	0.2800	0.6310	0.0056	0.0010	0.0023
July 1994	0.51	1.3676	0.2750	0.7130	0.0070	0.0014	0.0036
August 1994	0.56	1.2839	0.2900	0.6540	0.0072	0.0016	0.0036
September 1994	0.71	1.0177	0.3400	0.6770	0.0072	0.0024	0.0048
October 1994	0.46	1.0930	0.2850	0.7360	0.0050	0.0013	0.0033
November 1994	0.44	1.2716	0.2850	0.6820	0.0056	0.0012	0.0030
December 1994	0.53	1.0865	0.2900	0.8510	0.0057	0.0015	0.0043
January 1995	0.44	1.0173	0.2750	0.9050	0.0045	0.0012	0.0039
February 1995	0.46	1.0316	0.2700	0.7930	0.0470	0.0012	0.0036
March 1995	0.46	1.2729	0.2600	0.680	0.0059	0.0012	0.0030
April 1995	0.39	1.1865	0.2500	0.7890	0.0046	0.0009	0.0030
May 1995	0.48	1.3077	0.2750	0.6920	0.0063	0.0013	0.0033
Total	5.82				0.0693	0.0164	0.0417

Canopy area of cinnamon : 17.00 m^2
Number of trees : 1

Table. 11 Total litterfall and nutrient addition by bread fruit during the period from June 1994 to May 1995

Month	Litter fall (kg)	Nutrient content (%)			Nutrient addition (kg)		
		N	P	K	N	P	K
June 1994	1.58	1.1205	0.4150	0.770	0.0177	0.0065	0.0122
July 1994	1.62	1.3176	0.4200	0.830	0.0213	0.0068	0.0134
August 1994	1.82	1.2357	0.4200	0.825	0.0225	0.0076	0.0150
September 1994	1.92	0.9908	0.3950	0.810	0.0190	0.0075	0.0155
October 1994	1.69	1.0019	0.3950	0.795	0.0169	0.0066	0.0134
November 1994	1.84	0.9987	0.3600	0.685	0.0183	0.0066	0.0126
December 1994	2.13	0.9810	0.3505	0.645	0.0209	0.0074	0.0137
January 1995	2.06	1.0238	0.3600	0.710	0.0267	0.0094	0.0185
February 1995	2.11	1.0710	0.3550	0.700	0.0361	0.0074	0.0147
March 1995	1.39	1.1018	0.3750	0.800	0.0153	0.0052	0.0111
April 1995	1.29	1.1780	0.4100	0.815	0.0151	0.0052	0.0105
May 1995	1.22	1.0031	0.4050	0.795	0.0122	0.0049	0.0096
Total	21.22				0.2420	0.0812	0.1602

Canopy area of bread fruit : 23.00 m^2
Number of trees : 1

total quantity of dry litter produced during the year was 5.82 kg. The content of major nutrients in the litter varied from 1.0173 to 1.4825 per cent, 0.250 to 0.290 per cent and 0.6310 to 0.9050 per cent of N, P and K respectively. The total addition of nutrient were found to be 0.0693, 0.0164 and 0.0417 kg of N, P and K, respectively.

Bread fruit occupied an area of 23.0 m^2 and it produced 21.22kg of dry litter during the period (Table 11). Maximum litter production of 2.13 kg was noticed during December 1994 and the minimum quantity of 1.22 kg was noticed during May 1995. The nutrient concentration varied from 0.9810 to 1.3176 per cent in the case of N, 0.3505 to 0.4200 per cent in the case of P and 0.6450 to 0.8300 per cent in the case of K. Thus a quantity of 0.2420, 0.0812 and 0.1602 kg of N, P and K were cycled back to the system through the litterfall of bread fruit.

4.2.2 **Throughfall (Canopy wash)**

The nutrient addition by throughfall from coconut is shown in Table 12. The maximum quantity of throughfall and nutrient addition was during May 1995 and there was no addition during February 1995. N content in throughfall varied from 0.930 to 11.650 ppm, P content varied from 0.134 to 0.964 ppm and K content varied from 2.100 to 26.300 ppm. Totally 11.1946 kg N, 1.3560 kg P and 23.3525 kg K were added to the soil by throughfall from coconut alone.

Table. 12 Total throughfall and nutrient addition by coconut during the period (June 1994 to May 1995) in the homestead

Month	Total rain (mm)	Total quantity of canopy wash (litre)	Nutrient content (ppm)			Nutrient addition (kg)		
			N	P	K	N	P	K
June 1994	226.8	869823	1.09	0.210	3.80	0.9490	0.1827	0.1827
July 1994	237.8	919681	1.12	0.198	3.40	1.0300	0.1821	3.1264
August 1994	211.2	809994	0.93	0.164	2.60	07533	0.1328	2.1060
September 1994	68.9	264245	1.25	0.262	5.20	0.3304	0.0692	1.3741
October 1994	362.0	1388342	1.09	0.134	2.10	1.5133	0.1860	2.9155
November 1994	124.0	475565	3.55	0.290	8.00	1.6883	0.1379	3.8045
December 1994	9.0	34517	4.10	0.340	10.20	0.1415	0.0145	0.3521
January 1995	8.0	30682	5.95	0.420	14.60	0.1836	0.0129	0.4479
February 1995	0.0	0	-	-	-	0.0000	0.0000	0.0000
March 1995	13.7	52542	11.65	0.964	26.30	0.6121	0.0507	1.3819
April 1995	54.5	209018	5.68	0.410	8.60	1.1872	0.0857	1.7976
May 1995	364.0	1396012	2.01	0.216	4.20	2.8059	0.3015	5.8633
Total						11.1946	1.3560	23.3525

Total canopy area of trees : 4355.00 m^2
Number of trees : 96

In the case of jack (canopy area 215 m^2) the N content varied from 0.930 to 11.590 ppm, P content varied from 0.09 to 1.34 ppm and that of K content varied from 1.100 to 16.300 ppm. Thus, 0.4905, 0.0764 and 0.9315 kg of N, P and K, respectively were returned back to soil by throughfall from jack (Table 13).

The total quantity of nutrients added to soil through canopy wash of ailanthus was calculated to be 0.4232 kg N, 0.0506 kg P and 0.6603 kg K (Table 14). Nitrogen, phosphorus and potassium contents in throughfall of ailanthus varied from 0.790 to 24.170 ppm, 0.164 to 0.840 ppm and 1.750 to 36.850 ppm.

The two annona trees in the homestead, with a gross canopy area of 53.0 m^2 added 0.1864 kg N, 0.0091 kg P and 0.4230 kg K to the homestead(Table 15). The N content varied from 1.230 to 14.150 ppm (March 1995). Phosphorus content varied from 0.031 (October 1994) to 0.316 ppm (March 1995) and that of K varied from 3.600 (October 1994) to 22.6 ppm (March 1995). The nutrients added to soil by throughfall of annona were 0.1864 kg N, 0.0091 kg Pand 0.4230 kg K.

Gross canopy area occupied by pepper was 43.00 m^2 (Table 16). The nutrient contents of throughfall from pepper ranged from 1.860 to 9.840 ppm of N, 0.022 to 0.124 ppm of P and 2.400 to 23.600 ppm of K, respectively, during the period of study. The annual addition of

Table. 13 Total throughfall and nutrient addition by jack during the period (June 1994 to May 1995) in the homestead

Month	Total rain (mm)	Total quantity of canopy wash (litre)	Nutrient content (%)			Nutrient addition (kg)		
			N	P	K	N	P	K
June 1944	226.8	45034	1.12	0.27	2.60	0.0504	0.0122	0.1171
July 1994	237.8	47658	0.93	0.16	1.10	0.0443	0.0076	0.0524
August 1994	211.2	41974	1.52	0.13	3.20	0.0638	0.0055	0.1343
September 1994	68.9	13693	1.73	0.36	3.60	0.0237	0.0049	0.0493
October 1994	362.0	71945	1.60	0.09	1.80	0.1151	0.0065	0.1295
November 1994	124.0	24644	1.08	0.24	2.40	0.0266	0.0059	0.0591
December 1994	9.0	1789	3.16	0.62	3.80	0.0057	0.0011	0.0068
January 1995	8.0	1590	3.87	0.68	5.60	0.0062	0.0012	0.0089
February 1995	0.0	0000	-	-	-	0.0000	0.0000	0.0000
March 1995	13.7	2723	11.59	1.34	16.30	0.0316	0.0036	0.0444
April 1995	54.5	10831	3.15	0.44	6.40	0.0341	0.0048	0.0693
May 1995	364.0	72341	1.23	0.32	3.60	0.0890	0.0231	0.2604
Total						0.4905	0.0764	0.9315

Total canopy area of trees : 215.00 m^2
Number of trees : 2

Table. 14 Total throughfall and nutrient addition by ailanthus during the period (June 1994 to May 1995) in the homestead

Month	Total rain (mm)	Total quantity of canopy wash (litre)	Nutrient content (ppm)			Nutrient addition (kg)		
			N	P	K	N	P	K
June 1994	226.8	30866	1.760	0.198	2.750	0.0543	0.0061	0.0849
July 1994	237.8	32635	1.370	0.216	2.050	0.0447	0.0070	0.0669
August 1994	211.2	28743	1.150	0.264	2.350	0.0331	0.0076	0.0675
September 1994	68.9	9377	3.180	0.384	5.150	0.0298	0.0036	0.0483
October 1994	362.0	49166	0.790	0.164	1.750	0.0389	0.0081	0.0862
November 1994	124.0	16875	0.930	0.234	2.150	0.0157	0.0039	0.0363
December 1994	9.0	1225	3.180	0.360	9.850	0.0039	0.0004	0.1210
January 1995	8.0	1088	6.090	0.372	8.600	0.0066	0.0004	0.0094
February 1995	0.0	0	-	-	-	0.0000	0.0000	0.0000
March 1995	13.7	1865	24.170	0.840	36.850	0.0451	0.0016	0.0687
April 1995	54.5	7417	6.950	0.384	11.250	0.0515	0.0028	0.0834
May 1995	364.0	49538	2.010	0.184	1.950	0.0996	0.0091	0.0966
Total						0.4232	0.0506	0.6603

Total canopy area of trees : 163 m^2
Number of trees : 5

Table. 15 Total throughfall and nutrient addition by annona during the period (June 1994 to May 1995) in the homestead

Month	Total rain (mm)	Total quantity of canopy wash (litre)	Nutrient content (ppm)			Nutrient addition (kg)		
			N	P	K	N	P	K
June 1994	226.8	11066	1.230	0.042	4.600	0.0136	0.0005	0.0509
July 1994	237.8	11700	1.350	0.032	4.200	0.0158	0.0004	0.0491
August 1994	211.2	10305	2.310	0.046	6.100	0.0238	0.0005	0.0629
September 1994	68.9	3362	2.500	0.042	11.200	0.0084	0.0001	0.0377
October 1994	362.0	17663	2.160	0.031	3.600	0.0382	0.0005	0.0636
November 1994	124.0	6050	4.650	0.038	6.800	0.0281	0.0002	0.0411
December 1994	9.0	439	4.740	0.084	6.200	0.0021	0.0000	0.0027
January 1995	8.0	390	6.750	0.134	7.600	0.0026	0.0000	0.0029
February 1995	0.0	0	-	-	-	0.0000	0.0000	0.0000
March 1995	13.7	6690	14.150	0.316	22.600	0.0095	0.0002	0.0151
April 1995	54.5	2659	4.650	0.092	11.100	0.0124	0.0002	0.0295
May 1995	364.0	17761	1.800	0.362	3.800	0.03197	0.0064	0.0675
Total						0.1864	0.0091	0.4230

Total canopy area of trees : 53.00 m^2
Number of trees : 2

Table. 16 Total throughfall and nutrient addition by pepper during the period (June 1994 to May 1995) in the homestead

Month	Total rain (mm)	Total quantity of canopy wash (litre)	Nutrient content (ppm)			Nutrient addition (kg)		
			N	P	K	N	P	K
June 1994	226.8	9185	3.850	0.052	8.400	0.0354	0.0005	0.0772
July 1994	237.8	9712	2.370	0.036	5.600	0.0230	0.0003	0.0544
August 1994	211.2	8554	1.860	0.032	3.200	0.0159	0.0003	0.0274
September 1994	68.9	2790	4.130	0.044	4.600	0.0115	0.0001	0.0128
October 1994	362.0	14661	2.980	0.022	2.400	0.0437	0.0003	0.0352
November 1994	124.0	5022	3.010	0.030	2.800	0.0152	0.0002	0.0141
December 1994	9.0	364	2.750	0.048	3.600	0.0010	0.0000	0.0013
January 1995	8.0	324	4.050	0.096	9.100	0.0013	0.0003	0.0029
February 1995	0.0	0	-	-	-	0.0000	0.0000	0.0000
March 1995	13.7	555	9.840	0.124	23.600	0.0055	0.0001	0.0131
April 1995	54.5	2207	4.320	0.084	11.200	0.0095	0.0002	0.0247
May 1995	364.0	14472	2.870	0.032	6.800	0.0415	0.0005	0.0984
Total						0.2035	0.0028	0.3615

Total canopy area of plants : 43 .0 m^2
Number of plants : 78

nutrients to the soil was calculated to be 0.2035 kg N, 0.0028 kg P and 0.3615 kg K.

The throughfall wild jack contained a nutrient range of 3.080 to 17.020 ppm N, 0.240 to 3.600 ppm P and 6.100 to 32.400 ppm K during different months (Table 17). Annual addition of nutrients was estimated to be 0.2718 kg N, 0.0273 kg P and 0.5660 kg K through canopy wash of wild jack alone.

The annual quantity of nutrient addition in bilimbi from a canopy area of 34 m^2 by throughfall was calculated to be 0.2701 kg N, 0.0121 kg P and 0.7134 kg K (Table 18). The N, Pand K contents varied from 3.1 to 29.5 ppm, 0.16 to 0.68 ppm and 6.8 to 48.6 ppm respectively.

The nutrient concentration observed in mahogany ranged from 1.120 to 12.680 ppm for N, 0.125 to 0.480 ppm for P and 1.600 to 18.600 ppm for K at different months of the year. The annual quantum of nutrient addition was 0.0905 kg N, 0.0102 kg P and 0.1607 kg K (Table 19).

The bread fruit tree in the homestead returned 0.1684 kg N, 0.0010 kg P and 0.6593 kg K by throughfall (Table 20). The nutrient contents in throughfall ranged from 2.110 to 56.450 ppm N, 0.007 to 0.765 ppm P and 2.400 to 131.700 ppm of K with the least concentration during October 1994.

Table. 17 Total throughfall and nutrient addition by wild jack during the period (June 1994 to May 1995) in the homestead

Month	Total rain (mm)	Total quantity of canopy wash (litre)	Nutrient content (ppm)			Nutrient addition (kg)		
			N	P	K	N	P	K
June 1994	226.8	8924	3.980	0.260	8.300	0.0355	0.0023	0.0741
July 1994	237.8	9442	3.130	0.310	6.100	0.0296	0.0029	0.0576
August 1994	211.2	8310	3.940	0.360	7.800	0.0327	0.0030	0.0648
September 1994	68.9	2750	5.970	0.640	12.700	0.0164	0.0018	0.0349
October 1994	362.0	14343	3.080	0.240	6.400	0.0439	0.0034	0.0912
November 1994	124.0	4879	4.860	0.480	10.800	0.0237	0.0023	0.0527
December 1994	9.0	354	5.920	0.980	12.400	0.0021	0.0003	0.0044
January 1995	8.0	314	6.980	1.210	16.800	0.0022	0.0004	0.0053
February 1995	0.0	0	-	-	-	0.0000	0.0000	0.0000
March 1995	13.7	539	17.020	3.600	32.400	0.0092	0.0019	0.0175
April 1995	54.5	2144	7.890	0.980	14.800	0.0169	0.0021	0.0317
May 1995	364.0	14322	4.160	0.480	9.200	0.0596	0.0069	0.1318
Total						0.2718	0.0273	0.5660

Total canopy area of tree : 43 m^2
Number of trees : 1

Table. 18 Total throughfall and nutrient addition by bilimbi during the period (June 1994 to May 1995) in the homestead

Month	Total rain (mm)	Total quantity of canopy wash (litre)	Nutrient content (ppm)			Nutrient addition (kg)		
			N	P	K	N	P	K
June 1994	226.8	7156	3.21	0.22	9.8	0.0229	0.0016	0.0701
July 1994	237.8	7566	4.8	0.25	16.8	0.0363	0.0019	0.1271
August 1994	211.2	6664	5.6	0.18	13.6	0.3730	0.0012	0.0906
September 1994	68.9	2174	10.5	0.28	24.8	0.0228	0.0006	0.0539
October 1994	362.0	11442	3.1	0.16	6.8	0.0354	0.0018	0.0777
November 1994	124.0	3912	3.8	0.23	10.4	0.0149	0.0009	0.0407
December 1994	9.0	284	11.4	0.26	26.8	0.0032	0.0001	0.0076
January 1995	8.0	252	23.6	0.34	33.6	0.0059	0.0001	0.0085
February 1995	0.0	0	-	-	-	0.0000	0.0001	0.0000
March 1995	13.7	432	29.5	0.68	48.6	0.0127	0.0003	0.0210
April 1995	54.5	1720	15.1	0.31	26.9	0.0259	0.0005	0.0463
May 1995	364.0	11484	4.6	0.28	14.8	0.0528	0.0032	0.1699
Total						0.2701	0.0121	0.7134

Total canopy area of trees : 34.0 m^2
Number of trees : 1

Table. 19 Total throughfall and nutrient addition by mahogany during the period (June 1994 to May 1995) in the homestead

Month	Total rain (mm)	Total quantity of canopy wash (litre)	Nutrient content (ppm)			Nutrient addition (kg)		
			N	P	K	N	P	K
June 1994	226.8	6357	1.130	0.285	1.800	0.0072	0.0018	0.0114
July 1994	237.8	6720	2.670	0.195	4.200	0.0179	0.0013	0.0282
August 1994	211.2	5919	2.910	0.25	4.800	0.0172	0.0013	0.0284
September 1994	68.9	1931	3.950	0.250	6.500	0.0076	0.0005	0.0126
October 1994	362.0	10146	1.120	0.190	1.600	0.0114	0.0019	0.0162
November 1994	124.0	3475	1.310	0.125	1.900	0.0046	0.0004	0.0066
December 1994	9.0	252	1.810	0.225	3.500	0.0005	0.0001	0.0009
January 1995	8.0	224	3.870	0.195	9.300	0.0009	0.0000	0.0021
February 1995	0.0	0	-	-	-	0.0000	0.0000	0.0000
March 1995	13.7	384	12.680	0.480	18.600	0.0049	0.0008	0.0071
April 1995	54.5	1527	2.970	0.215	7.500	0.0045	0.0003	0.0115
May 1995	364.0	10202	1.350	0.175	3.500	0.0138	0.0018	0.0357
Total						0.0905	0.0102	0.1607

Total canopy area of trees : 31.0 m^2
Number of trees : 3

Table. 20 Total throughfall and nutrient addition by bread fruit during the period (June 1994 to May 1995) in the homestead

Month	Total rain (mm)	Total quantity of canopy wash (litre)	Nutrient content (ppm)			Nutrient addition (kg)		
			N	P	K	N	P	K
June 1994	226.8	4860	4.100	0.040	42.800	0.0199	0.0002	0.2080
July 1994	237.8	5138	4.610	0.028	9.600	0.0237	0.0001	0.0493
August 1994	211.2	4526	3.150	0.011	3.400	0.0143	0.0001	0.0154
September 1994	68.9	1476	6.650	0.028	11.600	0.0098	0.0000	0.0171
October 1994	362.0	7758	2.110	0.007	2.400	0.0164	0.0001	0.0186
November 1994	124.0	2657	8.120	0.015	13.500	0.0216	0.0001	0.0359
December 1994	9.0	193	8.600	0.060	19.900	0.0017	0.0000	0.0038
January 1995	8.0	171	21.500	0.090	62.100	0.0037	0.0000	0.0106
February 1995	0.0	0	-	-	-	0.0000	0.0000	0.0000
March 1995	13.7	294	56.450	0.765	131.700	0.0166	0.0004	0.0387
April 1995	54.5	1168	9.500	0.079	26.500	0.0110	0.0001	0.0310
May 1995	364	7800	3.080	0.048	29.600	0.0296	0.00004	0.2309
Total						0.1684	0.0010	0.6593

Total canopy area of trees : 23.0 m^2
Number of trees : 1

The mango tree in the homegarden returned 0.0725 kg N, 0.0008 kg P and 0.1455 kg K to the soil through canopy wash (Table 21). The N, P and K contents ranged from 1.050 to 12.500 ppm, 0.018 to 0.076 ppm and 2.200 to 32.400 ppm respectively at different months of the year.

Guava with a gross canopy area of 18.0 m^2 added 0.1345 kg of N, 0.0117 kg of P and 0.3323 kg of K by throughfall to the homestead soil (Table 22). The N content in the sample varied from 3.05 to 39.42 ppm, that of P from 0.19 to 0.98 ppm and that of K varied from 4.30 to 92.70 ppm with the minimum concentration during October 1994.

Cinnamon, with a canopy area of 17 m^2 contributed 0.0655 kg N, 0.0097 kg P and 0.1181 kg K by throughfall to the homestead (Table 23). The N content varied from 1.37 (October 1994) to 11.56 ppm (March 1995), P varied from 0.15 (October 1994) to 0.95 ppm (March 1995) and that of K varied from 2.8 (October 1994) to 19.2 ppm (March 1995).

4. 2. 3. **Stemflow**

The quantity of stemflow obtained from coconut varied from month to month (Table 24). The concentration of N, varied from 0.930 ppm to 6.560 ppm, P varied from 0.038 to 0.214 ppm and that of K

Table. 21 Total throughfall and nutrient addition by mango during the period (June 1994 to May 1995) in the homestead

Month	Total rain (mm)	Total quantity of canopy wash (litre)	Nutrient content (ppm)			Nutrient addition (kg)		
			N	P	K	N	P	K
June 1994	226.8	4794	1.950	0.026	4.000	0.0093	0.0001	0.0192
July 1994	237.8	5068	1.650	0.018	4.000	0.0084	0.0001	0.0071
August 1994	211.2	4464	1.550	0.022	2.200	0.0069	0.0001	0.0098
September 1994	68.9	1456	1.380	0.036	2.800	0.0020	0.0001	0.0041
October 1994	362.0	7651	1.050	0.022	2.600	0.0080	0.0002	0.0199
November 1994	124.0	2620	1.620	0.026	4.600	0.0042	0.0001	0.0121
December 1994	9.0	190	2.650	0.034	5.200	0.0005	0.0000	0.0009
January 1995	8.0	169	4.750	0.041	10.600	0.0008	0.0000	0.0018
February 1995	0.0	0	-	-	-	0.0000	0.0000	0.0000
March 1995	13.7	290	12.500	0.076	32.400	0.0036	0.0000	0.0094
April 1995	54.5	1151	7.600	0.024	12.400	0.0087	0.0000	0.0143
May 1995	364.0	7693	2.610	0.018	6.100	0.0201	0.0001	0.0469
Total						0.0725	0.0008	0.1455

Total canopy area of trees : 22.0 m^2
Number of trees : 1

Table. 22 Total throughfall and nutrient addition by guava during the period (June 1994 to May 1995) in the homestead

Month	Total rain (mm)	Total quantity of canopy wash (litre)	Nutrient content (ppm)			Nutrient addition (kg)		
			N	P	K	N	P	K
June 1994	226.8	3826	3.460	0.490	8.400	0.0132	0.0018	0.0321
July 1994	237.8	4045	3.150	0.360	6.500	0.0127	0.0015	0.0262
August 1994	211.2	3563	4.330	0.580	11.800	0.0154	0.0027	0.0420
September 1994	68.9	1162	6.950	0.650	18.600	0.0081	0.0008	0.0216
October 1994	362.0	6106	3.050	0.190	4.300	0.0188	0.0012	0.0263
November 1994	124.0	2092	4.000	0.710	6.900	0.0084	0.0004	0.0144
December 1994	9.0	152	6.930	0.520	28.600	0.0011	0.0001	0.0043
January 1995	8.0	135	13.590	0.750	34.100	0.0018	0.0001	0.0046
February 1995	0.0	0	-	-	-	0.0000	0.0000	0.0000
March 1995	13.7	231	39.420	0.980	92.700	0.0091	0.0002	0.0214
April 1995	54.5	919	17.590	0.630	41.500	0.1610	0.0006	0.0381
May 1995	364.0	6140	4.860	0.390	16.500	0.0298	0.0023	0.1003
Total						0.1345	0.0117	0.3323

Total canopy area of trees : 18.0 m^2
Number of trees : 1

Table. 23 Total throughfall and nutrient addition by cinnamon during the period (June 1994 to May 1995) in the homestead

Month	Total rain (mm)	Total quantity of canopy wash (litre)	Nutrient content (ppm)			Nutrient addition (kg)		
			N	P	K	N	P	K
June 1994	226.8	3469	2.610	0.560	4.000	0.0091	0.0019	0.0139
July 1994	237.8	3668	2.320	0.410	3.400	0.0085	0.0015	0.0125
August 1994	211.2	3230	2.610	0.270	5.800	0.0084	0.0009	0.0187
September 1994	68.9	1054	3.930	0.270	8.200	0.0041	0.0003	0.0086
October 1994	362.0	5537	1.370	0.150	2.800	0.0076	0.0008	0.0155
November 1994	124.0	1897	2.090	0.270	8.600	0.0040	0.0005	00163
December 1994	9.0	137	3.330	0.810	10.800	0.0005	0.0001	0.0015
January 1995	8.0	122	5.950	0.560	11.500	0.0007	0.0001	0.0014
February 1995	0.0	0	-	-	-	0.0000	0.0000	0.0000
March 1995	13.7	209.6	11.560	0.950	19.200	0.0024	0.0002	0.0040
April 1995	54.5	833	4.070	0.845	6.900	0.0034	0.0007	0.0057
May 1995	364.0	5568	3.010	0.480	3.600	0.0168	0.0027	0.0200
Total						0.0655	0.0097	0.1181

Total canopy area of trees : 17.0 m^2
Number of trees : 1

Table. 24 Total stemflow and nutrient addition by coconut during the period (June 1994 to May 1995) in the homestead

Month	Total rain fall (mm)	Total quantity of stemflow (litre)	Nutrient content (ppm)			Nutrient addition (kg)		
			N	P	K	N	P	K
June 1994	226.8	70735	1.390	0.085	1.510	0.0983	0.0060	0.1068
July 1994	237.8	73516	1.210	0.055	1.470	0.0890	0.0040	0.1081
August 1994	211.2	53793	1.390	0.093	1.550	0.0748	0.0050	0.0834
September 1994	68.9	12439	2.050	0.083	2.670	0.0255	0.0010	0.0332
October 1994	362.0	83170	0.930	0.038	1.030	0.0773	0.0032	0.0857
November 1994	124.0	25460	1.850	0.045	2.530	0.0471	0.0011	0.0101
December 1994	9.0	-	-	-	-	-	-	-
January 1995	8.0	-	-	-	-	-	-	-
February 1995	0.0	-	-	-	-	-	-	-
March 1995	13.7	-	-	-	-	-	-	-
April 1995	54.5	8782	6.560	0.214	16.890	0.0576	0.0019	0.1483
May 1995	364.0	92901	0.970	0.082	3.560	0.0901	0.0076	0.3307
Total						0.5597	0.0298	0.9063

Total canopy area of trees : 4355.00 m^2
Number of trees : 96

varied from 1.030 to 16.890 ppm. Total nutrient addition in the homestead by stemflow from coconut alone was worked out to 0.5597 kg N, 0.0298 kg P and 0.9063 kg K.

The concentration of N in the stem flow of jack varied from 0.750 to 5.620 ppm, that of P varied from 0.029 to 0.256 ppm and that of K recorded 1.150 to 9.850 ppm with minimum concentration during October 1994. There was an addition of 0.0011 kg N, 0.0005 kg P and 0.0026 kg K by the stemflow from jack during the period of study (Table 25).

The stemflow of mahogany recycled 0.0005 kg N, 0.0 kg P and 0.0008 kg K back to the soil (Table 26). The concentration of N varied from 0.560 to 1.210 ppm, P varied from 0.100 to 0.136 ppm and K varied from 0.730 to 4.670 ppm with least concentration during October 1994.

The content of N in the stemflow of ailanthus during the period varied from 0.680 to 10.130 ppm, P varied from 0.052 to 0.486 ppm and that of K varied from 2.050 to 49.860 ppm. Thus a total of 0.0054 kg N, 0.0003 kg P and 0.0111 kg K was returned to the soil by stemflow from ailanthus (Table 27).

The concentration of N in stemflow of cinnamon varied from 1.05 to 12.68 ppm, that of P varied from 0.034 to 0.366 ppm and that

Table. 25 Total stemflow and nutrient addition by jack during the period (June 1994 to May 1995) in the homestead

Month	Total rain fall (mm)	Total quantity of stemflow (litre)	Nutrient content (ppm)			Nutrient addition (kg)		
			N	P	K	N	P	K
June 1994	226.8	179	0.980	0.065	1.560	0.0002	0.0001	0.0003
July 1994	237.8	129	0.830	0.053	3.340	0.0001	0.0000	0.0004
August 1994	211.2	161	0.910	0.093	3.590	0.0001	0.0001	0.0006
September 1994	68.9	65	1.320	0.098	3.950	0.0001	0.0002	0.0003
October 1994	362.0	224	0.750	0.029	1.150	0.0002	0.0001	0.0003
November 1994	124.0	81	0.830	0.059	1.630	0.0001	0.0000	0.0001
December 1994	9.0	-	-	-	-	-	-	-
January 1995	8.0	-	-	-	-	-	-	-
February 1995	0.0	-	-	-	-	-	-	-
March 1995	13.7	-	-	-	-	-	-	-
April 1995	54.5	24	5.620	0.256	9.850	0.0001	0.0000	0.0002
May 1995	364.0	204	0.830	0.038	7.050	0.0002	0.0000	0.0004
Total						0.0011	0.0005	0.0026

Total canopy area of trees : 215.0 m^2
Number of trees : 2

Table. 26 Total stemflow and nutrient addition by mahogany during the period (June 1994 to May 1995) in the homestead

Month	Total rain fall (mm)	Total quantity of stemflow (litre)	Nutrient content (ppm)			Nutrient addition (kg)		
			N	P	K	N	P	K
June 1994	226.8	81	1.080	0.034	1.370	0.0001	0.00000	0.0001
July 1994	237.8	99	0.730	0.026	1.150	0.0001	0.00000	0.0001
August 1994	211.2	63	0.930	0.015	0.980	0.0001	0.00000	0.0001
September 1994	68.9	33	0.850	0.026	1.050	0.0000	0.00000	0.0000
October 1994	362.0	144	0.560	0.010	0.730	0.0001	0.00000	0.0001
November 1994	124.0	57	0.650	0.018	0.950	0.0001	0.00000	0.0001
December 1994	9.0	-	-	-	-	-	-	-
January 1995	8.0	-	-	-	-	-	-	-
February 1995	0.0	-	-	-	-	-	-	-
March 1995	13.7	-	-	-	-	-	-	-
April 1995	54.5	18	1.210	0.136	4.670	0.0000	0.00000	0.0001
May 1995	364.0	1204	0.021	0.93	0.000	0.0000	0.00000	0.0002
Total						0.0005	0.00000	0.0008

Total canopy area of trees : 31.0 m^2
Number of trees : 3

Table. 27 Total stemflow and nutrient addition by ailanthus during the period (June 1994 to May 1995) in the homestead

Month	Total rain fall (mm)	Total quantity of stemflow (litre)	Nutrient content (ppm)			Nutrient addition (kg)		
			N	P	K	N	P	K
June 1994	226.8	365	1.410	0.085	2.100	0.0005	0.0000	0.0008
July 1994	237.8	483	1.300	0.085	2.350	0.0006	0.0001	0.0011
August 1994	211.2	316	1.150	0.071	2.250	0.0004	0.0000	0.0007
September 1994	68.9	108	2.360	0.080	4.680	0.0003	0.0000	0.0005
October 1994	362.0	585	0.680	0.052	2.050	0.0004	0.0000	0.0012
November 1994	124.0	230	0.790	0.067		0.0002	0.0000	0.0011
December 1994	9.0	-	-	-	-	-	-	-
January 1995	8.0	-	-	-	-	-	-	-
February 1995	0.0	-	-	-	-	-	-	-
March 1995	13.7	-	-	-	-	-	-	-
April 1995	54.5	85	10.130	0.486	49.860	0.0009	0.0001	0.0042
May 1995	364.0	615	3.400	.095	2.390	0.0021	0.0001	0.0015
Total						0.0054	0.0003	0.0111

Total canopy area of trees : 163.0 m^2
Number of trees : 5

Table. 28 Total stemflow and nutrient addition by cinnamon during the period (June 1994 to May 1995) in the homestead

Month	Total rain fall (mm)	Total quantity of stemflow (litre)	Nutrient content (ppm)			Nutrient addition (kg)		
			N	P	K	N	P	K
June 1994	226.8	59	2.210	0.098	3.800	0.0001	0.00000	0.0002
July 1994	237.8	73	2.160	0.083	2.600	0.0002	0.00000	0.0002
August 1994	211.2	47	2.410	0.093	3.300	0.0001	0.00000	0.0002
September 1994	68.9	33	3.650	0.195	4.100	0.0001	0.00000	0.0001
October 1994	362.0	112	1.050	0.034	2.1400	0.0001	0.00000	0.0002
November 1994	124.0	46	1.380	0.065	2.3900	0.0000	0.00000	0.0001
December 1994	9.0	-	-	-	-	-	-	-
January 1995	8.0	-	-	-	-	-	-	-
February 1995	0.0	-	-	-	-	-	-	-
March 1995	13.7	-	-	-	-	-	-	-
April 1995	54.5	14	12.680	0.366	14.850	0.0002	0.00000	0.0002
May 1995	364.0	98	2.850	0.093	6.950	0.0003	0.00000	0.0007
Total						0.0011	0.0000	0.0019

Total canopy area of trees : 17.0 m^2
Number of trees : 1

of K varied from 2.14 to 14.85 ppm. By this way 0.0011 kg N and 0.0019 kg K were cycled back to the homestead (Table 28).

A total quantity of 0.0009 kg of N, 0.0 kg P and 0.0025 kg K were cycled back through stemflow of wild jack (Table 29). The concentration of N varied from 0.870 to 21.500 ppm and that of K varied from 1.190 to 26.180 ppm. The addition of P through stemflow was comparatively negligible in the case of wild jack.

The stemflow from bilimbi recorded a concentration range of 1.950 to 15.800 ppm, 0.044 to 1.164 ppm and 1.960 to 34.890 ppm of N, P and K respectively. Thus a total of 0.0008 kg N, 0.0 kg P and 0.0016 kg K were cycled back to the system by stemflow from bilimbi during the period of the study (Table 30).

4.2.4. **Livestock and poultry**

The data on the organic manure addition by live stock and poultry are furnished in Table 31. The cow and its calf produced 8760 kg of wet dung which contained an average of 0.234 per cent N, 0.093 per cent P and 0.159 per cent K. Addition of cowdung resulted in a nutrient input of 20.49 kg N, 8.15 kg P and 13.92 kg K into the system.

The goat unit comprising of two goats and two lambs produced

Table. 29 Total stemflow and nutrient addition by wild jack during the period (June 1994 to May 1995) in the homestead

Month	Total rain fall (mm)	Total quantity of stemflow (litre)	Nutrient content (ppm)			Nutrient addition (kg)		
			N	P	K	N	P	K
June 1994	226.8	63	1.010	0.041	6.810	0.0001	0.0000	0.0004
July 1994	237.8	81	1.830	0.041	6.300	0.0001	0.0000	0.0005
August 1994	211.2	69	2.130	0.035	7.550	0.0001	0.0000	0.0005
September 1994	68.9	18	4.500	0.073	8.900	0.0001	0.0000	0.0002
October 1994	362.0	119	0.870	0.023	1.190	0.0001	0.0000	0.0001
November 1994	124.0	56	0.930	0.031	3.170	0.0001	0.0000	0.0002
December 1994	9.0	-	-	-	-	-	-	-
January 1995	8.0	-	-	-	-	-	-	-
February 1995	0.0	-	-	-	-	-	-	-
March 1995	13.7	-	-	-	-	-	-	-
April 1995	54.5	9	21.500	0.198	26.180	0.0002	0.0000	0.0002
May 1995	364.0	129	1.090	0.043	3.150	0.0001	0.0000	0.0004
Total						0.0009	0.0000	0.0025

Total canopy area of trees : 43.0 m^2

Number of trees : 1

Table. 30 Total stemflow and nutrient addition by bilimbi during the period (June 1994 to May 1995) in the homestead

Month	Total rain fall (mm)	Total quantity of stemflow (litre)	Nutrient content (ppm)			Nutrient addition (kg)		
			N	P	K	N	P	K
June 1994	226.8	43	2.180	0.048	3.540	0.0000	0.00000	0.0002
July 1994	237.8	57	2.630	0.053	3.160	0.0000	0.00000	0.0002
August 1994	211.2	39	2.850	0.044	3.080	0.0001	0.00000	0.0001
September 1994	68.9	16	4.340	0.089	6.780	0.0001	0.00000	0.0001
October 1994	362.0	92	1.950	0.045	1.960	0.0002	0.00000	0.0002
November 1994	124.0	30	2.130	0.052	3.120	0.0001	0.00000	0.0001
December 1994	9.0	-	-	-	-	-	-	-
January 1995	8.0	-	-	-	-	-	-	-
February 1995	0.0	-	-	-	-	-	-	-
March 1995	13.7	2.3	15.800	0.164	34.890	0.0000	0.00000	0.0001
April 1995	54.5	9	4.100	0.081	11.890	0.0000	0.00000	0.0001
May 1995	364.0	108	2.600	0.057	4.560	0.0002	0.00000	0.0005
Total						0.0008	0.00000	0.0016

Total canopy area of trees : 34.0 m^2
Number of trees : 1

Table 31 Quantity, nutrient content and nutrient addition by livestock and poultry in the homestead during the period (June 1994 to May 1995)

Animal	Unit	Manure	Total quantity of manure added (kg)	Ave. nutrient content (%)			Nutrient addition (kg)		
				N	P	K	N	P	K
Cow + Calf	2	Wet dung	8760	0.234	0.093	0.159	20.49	8.15	13.92
Goat + Kids	4	Wet dung	412	0.538	0.217	0.830	2.22	0.90	3.41
Poutry	23	Poultry manure	923	1.68	1.120	1.090	15.50	10.33	10.06
Total			10095				38.21	19.38	27.39

412 kg dung which contained an average of 0.538 per cent N, 0.217 per cent P and 0.830 per cent K. The total nutrient addition from this source was 2.22 kg N, 0.90 kg P and 3.41 kg K in the homestead.

The poultry unit comprising of 23 birds produced 923 kg manure, which contained 1.68 per cent N, 1.12 per cent P and 1.09 per cent K. This has added 15.50 kg N, 10.33 kg P and 10.06 kg K to the soil during the period of the study.

The total quantity of nutrients from manure of livestock and poultry in the homestead was worked out to be 38.21 kg N, 19.38 kg P and 27.39 kg K.

4.3 Nutrient removal

The yield of various crops on dry matter basis, their nutrient contents and the nutrients removed by various crops in the homestead is depicted in Table 32. It was observed that the maximum quantity of nutrients was removed from the system by the harvested leaves and nuts of coconut which worked out to 14.35 kg N, 2.25 kg P and 9.05 kg K. This was followed by cassava. The top portion of the tapioca plants which was used as fire wood and the edible harvested tubers together removed 3.20 kg N, 1.15 kg P and 1.70 kg K from the homestead. The jack fruit removed 2.16 kg N, 0.60 kg P and 0.90 kg K. Amorphophallus tubers which had a dry weight of 59 kg removed 0.65 kg N, 0.35 kg P and 0.83 kg K. Papaya fruits removed 0.61 kg

Table 32 Nutrients removed from the homestead by harvested produce

Sl. No	Crop	Yield on dry wt basis(kg)	Nutrient content (%)			Nutrient removed		
			N	P	K	N	P	K
1.	Coconut leaves & nuts	2208	0.65	0.12	0.41	14.35	2.25	9.05
2.	Jack	201	1.08	0.293	0.445	2.16	0.60	0.90
3.	Cassava tubers	131	1.413	0.593	1.137	1.85	0.80	1.30
4.	Cassava tops	207	0.65	0.12	0.41	1.35	0.35	0.40
5.	Amorphophallus	59	1.081	0.591	1.382	0.65	0.35	0.83
6.	Papaya	53	1.117	0.621	0.933	0.61	0.34	0.50
7.	Pepper	13	1.431	0.375	1.501	0.19	0.05	0.20
8.	Bread fruit	18	1.112	0.213	0.377	0.21	0.04	0.07
9.	Wild Jack	9	1.130	0.392	0.538	0.11	0.04	0.05
10.	Rose apple	10	0.835	0.175	0.454	0.08	0.02	0.05
11.	Bilimbi	8	1.09	0.58	0.789	0.09	0.05	0.06
12.	Vegetables	3	0.98	0.345	1.31	0.04	0.01	0.05
13.	Colocasia	12	0.962	0.670	1.417	0.12	0.08	0.17
14.	Ginger	5	0.952	0.396	0.763	0.04	0.02	0.03
15.	Turmeric	3	0.853	0.392	0.684	0.02	0.01	0.01
16.	Annona	4	0.934	0.186	1.080	0.04	0.01	0.04
17.	Guava	16	1.280	0.675	1.326	0.21	0.11	0.21
18.	Banana	89	0.916	0.429	0.675	0.83	0.39	0.61
19.	Drumstick	17	0.731	0.462	0.489	0.12	0.08	0.17
20.	Mango	2	1.319	0.539	0.981	0.03	0.01	0.02
	Total	3068				23.04	5.97	14.59

N, 0.34 kg P and 0.5 kg K from the system. The removal by pepper (0.19 kg N, 0.05 kg P and 0.20 kg K), bread fruit (0.21 kg N, 0.04 kg P and 0.07 kg K) and wild jack (0.11 kg N, 0.04 kg P and 0.05 kg K) was substantial in the homestead. In the case of banana, the fruits and leaves removed 0.83 kg N, 0.39 kg P and 0.61 kg K out of the homestead through the harvested produce. Guava (0.21 kg N, 0.11 kg P and 0.21 kg K), drumstick (0.12 kg N, 0.08 kg P and 0.17 kg K) and colocasia (0.12 kg N, 0.08 kg P and 0.17 kg K) also removed nutrients from the homestead. The nutrients removed by all other crops individually were found to be less when compared with the above mentioned crops.

Thus, the total nutrient removal by way of harvested produce from the system was 23.04 kg N, 5.97 kg P and 14.59 kg K.

4.4 Soil properties

4.4.1 Physical properties

The data on soil physical properties of the homestead are given in the Tables 33. It is seen that the soil moisture content, both at 15 cm and 30 cm depth, recorded a higher value in the homestead soil than the open soil (Table 33). Among the other physical properties of soil, water holding capacity was found to be higher in the homestead soil than the open (Table 34). Similar trends were observed with respect to porosity also. In the case of bulk density, homestead soils

Table. 33 Soil moisture status of the homestead and control at two depths at monthly intervals

Month	Depth (cm)	Moisture content (%)	
		Open (control)	Homestead
June 1994	15	12.82	14.42
	30	14.73	15.03
July 1994	15	13.54	15.61
	30	15.26	17.02
August 1994	15	11.21	14.24
	30	13.15	15.78
September 1994	15	10.43	12.76
	30	12.52	13.81
October 1994	15	13.97	15.26
	30	15.54	17.31
November 1994	15	11.07	13.46
	30	12.92	15.91
December 1994	15	8.23	11.62
	30	11.56	13.57
January 1995	15	6.53	10.43
	30	9.78	11.67
February 1995	15	5.46	8.38
	30	7.32	10.08
March 1995	15	9.61	10.11
	30	10.43	10.57
April 1995	15	10.46	11.33
	30	12.52	12.97
May 1995	15	13.21	14.53
	30	15.67	15.99

Table. 34 Soil physical properties of the homestead and control at half yearly intervals

Soil property	June 1994		December 1994		May 1995	
	Control	Homestead	Control	Homestead	Control	Homestead
Water holding capacity (%)	36.89	46.54	37.12	41.56	37.24	44.37
Porosity (%)	43.65	52.03	43.33	48.88	44.44	50.18
Bulk density (g/cc)	1.51	1.30	1.53	1.37	1.50	1.34
Particle density (g/cc)	2.68	2.71	2.70	2.68	2.70	2.69

Table. 35 Soil chemical properties of homestead and control at half yearly intervals

Soil property	Depth (cm)	Homestead			Control		
		June 1994	Dec 1994	May 1995	June 1994	Dec 1994	May 1995
Available N (kg ha^{-1})	0 - 30	342.80	349.10	353.40	219.50	226.40	228.10
	30 - 60	271.36	246.42	245.34	174.24	181.61	180.40
Available P (kg ha^{-1})	0 - 30	57.90	54.23	56.13	39.60	43.40	41.08
	30 - 60	41.63	43.01	43.18	32.41	31.11	32.74
Available K (kg ha^{-1})	0 - 30	303.00	315.62	310.11	142.60	125.63	138.67
	30 - 60	285.40	300.10	298.46	110.32	98.90	108.81
Organic carbon (%)	0 - 30	0.81	0.84	0.85	0.63	0.58	0.64
	30 - 60	0.62	0.63	0.61	0.43	0.48	0.47
pH	0 - 30	5.40	5.36	5.30	5.90	5.84	5.87
	30 - 60	5.85	5.75	5.69	6.01	5.97	5.92

recorded lower values than those of the control, whereas in the case of particle density, variation between homestead soil and control plot was negligible.

4.4.2 Chemical properties

Comparison of chemical properties of the homestead soil with that of the control is presented in Table 35. The data reveal that the available N, P and K status at 30 cm and 60 cm depth were considerably higher in homestead soil than in the open soil (control). The available N content varied from 342.80 kg to 353.40 kg ha^{-1} in the case of homestead soil at 0- 30 cm depth and 245.34 to 271.36 kg ha^{-1} at 30 - 60 cm depth. In the case of control, it varied from 219.50 to 228.10 kg ha^{-1} and 174.24 to 181.61 kg ha^{-1} at 0 - 30 cm and 30 - 60 cm depths respectively.

In the case of P,the content varied from 54.23 to 57.9 kg ha^{-1} and 41.63 to 43.18 kg ha^{-1} at 0 - 30 and 30 - 60 cm of depths respectively in the case of homestead soil. In the case of control, it recorded a range from 39.60 to 43.40 kg ha^{-1} and 31.11 to 32.74 kg ha^{-1} at 0 - 30 and 30 - 60 cm depths respectively, which is substantially lower than that of the homesead soil. In homestead soil, K content varied from 303.00 to 315.62 kg ha^{-1} and 285.40 to 300.10 kg ha^{-1} at 0-30 cm and 30-60 cm depths respectively. In the case of control, it recorded a range of 125.63 to 142.60 kg ha^{-1} and 98.90 to 110.32 kg ha^{-1} at 0-30 cm and 30-60 cm depth respectively.

The organic carbon content in the homestead soil was observed to be more than that in the control. At 0-30 cm depth it varied from 0.81 to 0.85 per cent and 0.58 to 0.64 per cent in homestead and control respectively. A similar trend was also observed in the case of organic carbon at 30-60 cm depth in homestead and control.

The pH of the homestead soil was found to be less than (ranged from 5.3 to 5.97) that of the open, at both 0-30 and 30-60 cm depths.

4.4.3 Microbial population

Data on the nature and number of micro-organisms in the homestead and control are given in Table 36. Immense microbial activity was observed in the homestead as compared to open space. In all the cases, highest microbial population was obtained during May 1995 and the least, during December 1994. In the case of fungus, the values ranged from 36.00 x 10^4 to 167.00 x 10^4 and 10.00 x 10^4 to 73.00 x 10^4 in the homestead and control, respectively. Unlike in the other observations, the bacteria population of open space recorded a higher observation during June 1994 with a number of 40 x 10^8, while in homestead, it was 13.00 x10^8 . The bacterial population ranged from 7.00 x 10^8 to 40.00 x10^8 and 3.00 x 10^8 to 40.00 x 10^8 in case of

Table. 36 Microbial population of the homestead and control at half yearly intervals

Microorganisms	June 1994		December 1994		May 1995	
	Home	Control	Home	Control	Home	Control
Fungus (10^4)	87.00	39.00	36.00	10.00	167.00	73.00
Bacteria (10^8)	13.00	40.00	7.00	3.00	40.00	14.00
Actinomycetes (10^6)	3.00	1.00	1.33	0.33	5.00	1.00
Phosphorus solubilising bacteria (10^6)	5.00	2.00	1.00	0.66	6.00	3.33

Figures indicate the population per gram of soil

Table. 37 Monthly average of temperature, total rainfall,relative humidity and soil temperature in the Homestead and control

Month	Temperature (^{0}C)		Total Rain fall (cm)	Relative humidity (%)		Soil Temperature (^{0}C)			
	Maximum	Minimum		Control	Home stead	Control		Homestead	
						15 cm	30 cm	15 cm	30 cm
June 1994	29.44	24.50	22.70	85.72	85.42	27.5	29.7	25.4	27.1
July 1994	29.24	23.70	23.80	84.15	83.60	27.8	29.5	25.2	27.3
August 1994	28.50	22.90	21.10	83.25	83.26	26.6	28.6	24.8	26.6
September 1994	31.16	23.10	6.90	85.96	84.86	28.7	30.7	27.7	29.7
October 1994	27.56	23.23	36.20	83.60	82.84	29.2	31.0	28.1	29.1
November 1994	28.83	25.67	12.40	83.60	82.76	29.3	32.2	29.1	31.0
December 1994	28.12	22.41	0.90	81.23	82.33	30.5	32.6	29.5	31.6
January1995	27.70	21.82	0.80	77.36	79.00	31.1	32.9	30.0	32.0
February 1995	29.32	25.56	0.00	71.77	74.33	32.3	34.8	32.0	34.0
March 1995	31.07	24.22	1.40	72.05	74.71	31.8	33.7	31.6	33.2
April 1995	30.52	23.81	5.50	76.53	76.58	29.9	32.8	29.5	32.1
May 1995	29.67	23.54	36.40	78.33	77.65	29.3	31.5	29.2	30.9

homestead and control respectively. In the case of actinomycetes also a pattern similar to that of fungus was observed. It ranged from 1.33 x 10^6 to 5.00 x 10^6 in case of homestead soil, while it ranged from 0.33 x 10^6 to 1.00 x 10^6 in control. The counts observed in the case of P solubilising bacteria had a range of 1.00 x 10^6 to 6.00 x 10^6 and 0.66 x 10^6 to 3.33 x10^6 in homestead and control, respectively.

4.5 **Micro climate**

The mean monthly maximum temperature recorded in the homestead during the period under study ranged from 27.56 to 31.16 ^{0}C and that of minimum temperature ranged from 21.82 to 25.67^{0}C (Table 37). The total rainfall received during the period was 1681 mm.

4.6.1 **Relative humidity**

The monthly mean relative humidity in homestead and control is furnished in Table 37. The relative humidity of homestead and control showed variation between months. During rainy season, the open space recorded a slightly higher value, while during the months of little or no rain, relative humidity was higher in the homestead.

4.5.2 **Soil temperature**

The data on the soil temperature at 15 cm and 30 cm depth is given in the Table 37. In all cases, soil temperature at the homestead was found to be lower than that in the open space. Soil temperature at

15 cm depth varied from 24.8 to 32.0 ^{0} C and 26.6 to 32.3 ^{0} C, in the homestead and control respectively. The maximum difference in temperature between the homestead and control recorded a value of 2.6 ^{0} C during the month of July 1994 at 15 cm depth and 2.6 ^{0} C during the month of June 1994 at 30 cm depth.

4.6 Light intensity

The monthly variation in the light intensity at the floor of the major tree species in the homestead and control is presented in Table 38. It is evident from the data that the light intensity at the floor of all the trees were always less than that in the open. The maximum light intensity recorded during the period of study was 83900 lux during February 1995 in the open space. The least value recorded in the open was 56300 lux during May 1995. The percentage of light transmitted by the different tree species was also worked out. It was observed that the maximum infiltration of light was recorded in coconut followed by ailanthus, jack and mahogany. The percentage of light infiltration varied from 22.74 to 29.44, 11.37 to 17.34, 14.03 to 22.47 and 6.75 to 13.64 per cent for coconut, jack, ailanthus and mahogany respectively.

4.7 Economic analysis

The economic analysis of the homestead is presented in Table 39. Out of the 4840 m^2 of the total homestead area, the space

Table. 38 Light intensity (lux) at the floor of major tree species and control

Month	Coconut	Jack	Ailanthus	Mahogany	Control
June 1994	16500 (25.70	9700 (15.11)	11700 (18.22)	6400 (9.97)	64200 (100)
July 1994	17300 (24.89)	10500 (15.11)	12200 (17.55)	7500 (10.79)	69500 (100)
August 1994	17800 (24.86)	10800 (15.08)	18500 (18.85)	7900 (11.03)	71600 (100)
September 1994	19200 (26.97)	12100 (16.99)	13800 (19.38)	9000 (12.64)	71200 (100)
October 1994	15700 (26.30)	10000 (16.75)	11200 (18.76)	7100 (11.89)	59700 (100)
November 1994	16500 (26.48)	10800 (17.34)	14000 (22.47)	8500 (13.64)	62300 (100)
December 1994	20500 (28.35)	11200 (15.49)	14000 (19.36)	8800 (12.17)	72300 (100)
January1995	22100 (29.23)	11800 (15.61)	15300 (20.24)	9800 (12.96)	75600 (100)
February 1995	24700 (29.44)	13400 (15.97)	15100 (17.99)	9600 (11.44)	83900 (100)
March 1995	22900 (29.28)	10600 (13.55)	13800 (17.65)	7900 (10.10)	78200 (100)
April 1995	21100 (28.86)	11500 (15.73)	13600 (18.60)	8300 (11.35)	73100 (100)
May 1995	12800 (22.74)	6400 (11.37)	7900 (14.03)	3800 (6.75)	56300 (100)

Figures in paranthesis represent percentage transmission

Table. 39 Economic analysis of the homestead

Sl. No	Enterprise	Popul-ation	Space used m²	Labour cost (Rs)	Other expenses(Rs)	Total expenditure (Rs)	Gross return (Rs)	Net return (Rs)	B:C ratio
1	Adult coconut	96 nos.	4355	2068	3024	5092	22008	16916	4.32
2	Young coconut	8 nos.	187	84	280	364	0000	-364	-
3	Banana(Palayan kodan)	50 nos.	256	350	175	525	768	243	1.46
4	Tapioca	-	320	168	96	264	720	456	2.72
5	Amorphophallus	80 nos.	190	210	318	528	784	256	1.48
6	Coconut + pepper	42 nos.	59	60	75	135	763	628	5.65
7	Erythrina+ pepper	36 nos.	17	57	79	136	654	518	4.80
8	Colocasia	-	80	25	32	57	108	51	1.80
9	Ginger	-	38	55	78	133	282	149	2.12
10	Turmeric	-	35	19	25	44	83	39	1.80
11	Curry leaf	7 nos.	11	15	24	39	210	171	6.36
12	Chekurmanis	18 nos.	23	10	22	32	180	148	5.62
13	Drumstick	6 nos.	26	10	18	28	85	57	3.03
14	Bread fruit	1 no.	23	10	26	36	110	74	3.05
15	Jack	2 nos.	215	95	52	147	875	728	5.95
16	Mango	1 no.	22	22	13	35	30	-5	0.85
17	Guava	1 no.	18	24	32	56	206	150	3.62
18	Papaya	3 nos.	12	25	16	41	180	139	4.39
19	Wild jack	1 no.	43	18	24	42	24	-18	0.57
20	Cinnamon	1 no.	17	23	15	38	22	-16	0.58
21	Ailanthus	5 nos.	163	69	102	171	00	-171	0.00
22	Mahogany	3 nos.	31	24	46	70	00	-70	0.00
23	Rose apple	1 no.	11	18	26	114	218	104	1.91
24	Vegetables	-	160	35	39	74	265	191	3.58
25	Annona	2 nos.	53	18	12	30	36	6	1.20
26	Bilimbi	1 no.	34	12	23	35	76	41	2.17
27	Cow + calf	2 nos.	23	1575	7320	8895	12531	3636	1.40
28	Goat + kids	4 nos.	15	375	636	1011	2434	1423	2.40
29	Poultry	23 birds	22	490	720	1210	2129	919	2.17
30	House & permanent structures	-	222	-	-	-	-	-	-
	Total		6681	5964	13348	19312	45781	26469	2.37

available for cropping was 4558 m^2. The gross cropped area and the cropping intensity was calculated and found to be 6399 m^2 and 140 per cent respectively.

The data on the economic analysis of the homestead during the period of study revealed that the labour charges and other expenses in the homestead was Rs 5964/- and Rs.13348/- respectively. Thus the total expenditure for the period was worked out to be Rs. 19312/-. The data also showed that the gross returns by different farming activities was Rs. 45781/- and the net returns was calculated to be Rs. 26469/-. An amount of Rs. 5070/- was found to be saved by the farmer through the contribution of family labour, which was equivalent to 84.5 man days. The benefit:cost ratio of the homestead was worked out to be 2.37.

Among the perennial crops, coconut gave the highest benefit:cost ratio of 4.32, whereas, the benefit:cost ratio further increased with pepper. Some of the homegarden perennial crops like curryleaf, chekurmanis, guava and papaya also showed a comparatively higher benefit:cost ratio. Timber trees could not generate any profit.

DISCUSSION

DISCUSSION

Home gardens are considered to be one of ancestral cropping systems followed by the farmers of Kerala from time immemorial. A home garden is an assemblage of trees, crops and animals, maintained by the farmers for meeting the basic needs of the farm family. In this system, the farmer cultivates an array of crops, at different spatial and temporal arrangements, resulting in a high cropping intensity. High density coupled with unscientific planting of various components results in very low productivity in the homestead. There is stiff competition between the different components in the homestead for nutrients, sunlight and space. The present project undertook a detailed investigation on the functioning and dynamics of a selected homestead in Thiruvananthapuram district with 26 components. The results of the study carried out on the nutrient addition by various components and subsequent soil productivity aspects, microclimate and the economics of the system are discussed in this chapter.

5.1 Structure and function

A conspicuous structural characteristic of the homesteads in the State is the great diversity of the species, varying from annuals to large multipurpose trees, and animals. In between several trees, shrubs and vines occupy different vertical layers, thus creating a forest like multi-storey canopy structure in the homestead. The peculiar combination of the annual and perennial crops grown in association, commonly exhibits a multi-layered vertical structure of trees, shrubs and ground cover plants in the homestead. Fernandes and Nair (1986) observed the presence of different crops, livestock and poultry production in the homesteads under different situations. According to Maydell (1987), livestock in the homestead represents an important capital asset and a source of income in addition to agricultural crops. Socially, keeping livestock provided employment to unsalaried members of the farm family and used crop by-products and residues, and improved the soil productivity of marginal lands. The different crop components in the homestead include, food, fodder and cash crops, vegetables and commercial crops. The choice of an enterprise is based on the needs and resources of the farmer and market demand for the commodity. The home gardens in the State exhibit the features of a typical agroforestry system which ideally combines the ecological functions of forest with those of providing the socio-economic needs of the people (Soemarwoto and Soemarwoto, 1984 ; Fernandes and Nair, 1986).

5.1.1 **The experimental homestead**

The selected homestead had a net area of 4840 m^2. About 5 per cent of the area was utilized for permanent structures like buildings for the farmer and shelter for the animals. The rest was planted with different crops.

The topography of the land was plain. The soil type belonged to the typical red loam soils of Neyyattinkara taluk. The rainfall received during the period of study was 1681 mm with fairly good distribution. A well was the only source of irrigation available in the homestead, with a 0.5 HP pump set. The pump set was used for meeting the water requirements of the household and cattle. The water was also used for irrigating the vegetable crops during the summer months.

5.1.2. **Farm family**

The farm family consisted of seven members, which included the farmer, his wife, two children, farmer's two brothers-in-law and his mother-in-law, Smt. Naliniamma, who owned the property. Her two sons are employed outside the district. Since the earning members are engaged in non-agricultural activities, the farm family had engaged two servants to look after the day to day activities of the homestead and home. The family members had undertaken other employments since the income generated from the homestead was not sufficient to meet the various needs of the family.

The main source of income of the family was from off-farm employment. The family members provided a labour input of 84.5 mandays for various activities in the homestead during the period of study. Abdul Salam *et al.* (1992 a) estimated a labour input of 182 mandays by a four member agricultural family. The lower labour input in the present study might be due to the off-farm activities of the members of the family and the assistance of two permanent labourers in the homestead.

5.1.3. Crops and cropping pattern

The inventory (Table 1) revealed that the homestead accomodated of 26 crops/tree species resulting in a high cropping intensity of 140 per cent. The intensive cropping nature of the homesteads in Kerala has been reported by Nair and Sreedharan (1986), Abdul Salam *et al.* (1992 a) and Happy Mathew (1993).

The major perennial tree crop of the homestead was coconut with a population of 96 adult bearing and eight non-bearing trees (Table 1). Coconut being the major crop, which sustained the family with maximum income, the homestead can be considered as a coconut-based system. The predominance of coconut in the homesteads of Kerala has been reported by Nair and Sreedharan (1986) and Abdul Salam *et al.* (1992 a). According to Nair (1979), the main reason for the dominance of coconut palms was the easiness to manage the crop and its low labour requirement.

The crop selection, sequence, arrangement and planting in one homestead are usually based on the requirement, convenience and perception of the farmer. However, a distinct vertical zonation of the components could be observed in the garden. The trees like coconut, jack, wild jack, ailanthus and mahogany occupied the top most layer (>20 m). Crops like cinnamon, guava, bread fruit, bilimbi, annona and mango occupied the second layer (10- 20 m). Pepper was grown using coconut and erythrina as the standards and was allowed to grow upto 4 m from the ground. Crops like cassava, amorphophallus, colocasia, chekurmanis, curry leaf and vegetables occupied the next layer of upto 2 m height and the ground layer was occupied by ginger and turmeric. This pattern of arrangement of tree / crop components ensured efficient utilization of space and harvesting of solar energy. The cropping pattern adopted by the farmer was in such a way that solar energy could be tapped to the maximum by arranging different crops in different vertical zones. The structural arrangement, canopy configuration and component interaction of the homestead was similar to those of other homegardens described by Michon (1983) and Okafor and Fernandes (1987).

In the case of coconut, the nut production from the homestead during the year of study was 6813, with an average production of 71 nuts per tree per annum. Apart from harvesting, which was done once in 45 days, the other important operations in coconut farming included, the intercultivation and opening of basins during the onset of monsoon in June-July. Due to the presence of cattle the farmer had taken care to give sufficient organic manure to the coconut palms, at an average rate of 70 kg of cowdung per palm per year. The young palms were also managed well with intercultivation, weeding and manuring as in the case of adult palms. For the maintenance and intercultivation of coconut palms, 35 labourers were engaged during the period of study. Nelliat and Krishnaji (1976) estimated a labour requirement of 150 mandays per year for one hectare of pure coconut plantation. The annual requirement of labour for the various operations for coconut and intercrops in the homestead was 89 mandays.

The major component in the homegarden next to coconut was jack, a crop which does not require much intercultivation or management at any stage. The annual labour requirement for the two jack trees was almost negligible. The jack trees produced a total of 112 fruits during the period of study, out of which, 21 were used for home consumption and the rest were sold locally. According to the farmer, his intention was to use these trees for timber purpose after a period of 60 years.

Five ailanthus trees of approximately six years of age were grown in the homestead for timber purpose. Digging the base and applying 15 kg of cowdung per plant during the month of June was the only cultivation practice done. The growth of the trees was satisfactory. These trees acted as soil ameliorative and provided soft wood for match industry, fetching premium price after a period of ten years.

Other multipurpose trees present in the homestead were mahogany and wild jack. These trees were also maintained for timber purpose, their branches and twigs were pruned heavily to enhance the growth of main stem. The pruned branches were used as organic manure. Intercultivation operations were not undertaken for any of these crops. Fruit trees like mango, breadfruit and bilimbi were also present in the homestead. These were maintained for home consumption. None of them were improved varieties. The sale of fruits obtained from guava, bilimbi and annona fetched some income to the farmer (Table 39). A cinnamon tree was also grown in the homestead by the farmer which was used for culinary purpose as a spice.

In addition to the above fruit trees, the major annual fruit crop cultivated in the homestead was banana. About 50 banana (var. palayankodan) plants were cultivated in the interspaces of coconut. Three papaya plants (local variety) were also grown in the homestead.

Cassava, colocasia and amophophallus were the main tuber crops cultivated in the interspaces of coconut in the homestead. According to Nelliat and Krishnaji (1976) tuber crops are best suited for intercropping in rainfed coconut gardens to minimise the risk of farming.

A high yielding variety of pepper (var. Panniyur-1) was an important component of the homestead. Out of the 78 pepper vines in the homestead 42 were trailed on coconut and 36 on erythrina. The growth and yield of pepper were found to be satisfactory.

Ginger and turmeric occupied the ground layer and were grown in the interspaces of coconut and ailanthus. Curry leaf, planted along the bunds, and was found to be most useful for culinary preparations.

Vegetables like tomato, bittergourd, snakegourd, brinjal, bhindi, chillies and cowpea were cultivated at different seasons of the year in the interspaces of the coconut palms near the kitchen. Chekurmanis and drumstick were the perennial vegetables grown in the homestead, mainly along the bunds near the cattle shed. Cow dung from the cattle was used as manure for these crops.

Thus the farmer cultivated an array of intercrops in the interspaces of the perennial trees in the home garden. The prevalence of intercropping in between tree crops is a common feature in the homesteads of Kerala (Abdul Salam *et al.*, 1992a and Happy Mathew, 1993). Intercropping reduced the risk involved in monocropping and increased the total net return. The minimisation of risk by intercropping in coconut garden has also been reported by Nair (1984).

5.1.4 **Livestock and poultry**

The homestead had one milch cow and its calf , two goats and two lambs and 23 poultry birds. The cow yielded 1277.5 litres of milk and the goat provided 182.5 litres of milk during the period of study. From the poultry birds, 1594 eggs were obtained. The animals were fed with green grass and leaves of banana, available from the homestead. The fodder available in the homestead was insufficient to meet the demand of cattle and hence supplemented by paddy straw and concentrates. About one tonne of straw was purchased locally at the rate of Rs. 0.5 per kg during the period of study. The goats were fed with weeds and green leaves of jack and erythrina from the homestead and nearby fields. The excess milk after the consumption by the family members was sold to the neighbours.

5.1.5. Marketing

Most of the products obtained from the homegarden were consumed and the surplus was sold locally. However, in the case of pepper, the same was sold at Nedumangad market. The sale of the farm produce fetched reasonably good prices.

The major commodities marketed were nuts of coconut, coconut leaves, cassava, amorphophallus, jack fruit, vegetables, milk and eggs. Except in the case of milk, the price varied according to demand and season. Systematic marketing was not seen in the sale of farm produce. The sale of produces mainly took place by negotiation and bargaining. In the case of coconut and pepper, involvement of middlemen was noticed and in all other cases, the farmer enjoyed the benefit of direct selling to the consumers locally.

5.2. Nutrient cycling

One of the main principles in soil management in agroforestry is to make best use of the resource-conserving and resource-sharing potential of trees. Nutrient cycling processes, that take place in varying degrees in all land-use systems, become particularly relevant in homegardens because of the favourable effects of trees on such process.

A part of the nutrients that is taken up by plants is returned to the soil through two avenues viz., litterfall and plant cycling. Plant cycling constitutes that part of the total uptake of nutrients which is again leached out from the vegetative parts through crown wash occuring as throughfall and stemflow. The total amount involved in cycling depends on the nutrient content of leaves, intensity and frequency of rainfall, and the age and arrangement of leaves (Ulrich *et al.* 1977). From the point of view of plant nutrition, this process is very important. The results of the study carried out to assess the nutrient cycling in the home garden are discussed with respect to litterfall, throughfall and stemflow.

5.2.1 Litterfall

The litterfall from the multipurpose trees forms a major component of the nutrient cycling in any agroforestry system. In the present study, the total litter production from the ten tree species in the homestead, was 384.64 kg, which resulted in a nutrient input of 4.3543, 1.1661 and 3.0231 kg of N, P and K respectively (Table 40).

Among the tree species, jack added the highest quantity of litter (138.41 kg) and accounted for 36 per cent of the total litterfall in the homestead (Table 2). This was followed by ailanthus (99.77 kg). The litter addition by cinnamon tree (5.82 kg) was found to be the lowest. The results are in conformity with the findings of Happy Mathew (1993), who reported that the annual litter production had a positive correlation with the canopy area of the trees. In the present study also, the annual litterfall was in proportion to the canopy area, Further, the genetic character of the species might also have had an influence on the leaf shedding and litter production.

It is also evident from the Tables 2 to 12 that, within the same species there was considerable variation in the litter production during the different months of the year. Maximum litterfall was noticed during January in the case of jack, ailanthus and bread fruit, whereas, in mango, maximum litter production was noticed during August. In cinnamon it was during September, 1994. The variation in the litterfall could be assumed to be a genetic character of the different species in relation to variation in climatic factors which indirectly influences the phenology of trees. It was noticed that for majority of the trees, maximum litterfall occurred during January with the onset of summer. As reported by Ashton (1975) in the case of *Eucalyptus*

Table 40 **Canopy area, annual litter production, and total nutrient addition by different trees of the homestead**

Sl. No	Tree	Gross canopy area (m^2)	Annual litter production (kg)	Annual nutrients addition (kg.)		
				N	P	K
1	Jack	214.66	138.4	1.4680	0.3906	0.5606
2	Ailanthus	163	99.77	1.2202	0.3026	1.4393
3	Anona	54.84	23.87	0.2481	0.0550	0.1033
4	Wild jack	43.01	33.43	0.3772	0.1270	0.2960
5	Bilimbi	34.21	28.34	0.3542	0.1121	0.1423
6	Mahogany	30.86	16.71	0.1902	0.0308	0.1015
7	Bread fruit	22.98	21.22	0.2420	0.0812	0.1602
8	Mango	22.90	9.69	0.1063	0.0250	0.1328
9	Guava	18.09	7.39	0.0798	0.0254	0.0454
10	Cinnamon	16.6	5.82	0.0693	0.0164	0.0417
	Total	621.15	384.64	4.3543	1.1661	3.0231

regans leaf fall was maximum in the summer months. It may be due to the innate mechanism of the trees to prevent the loss of water through stomata of leaves by shedding leaves during the summer months.

Thus, it can be concluded that the litterfall in the present study, varied between species and season. The results are in conformity with that of Pushp and Surendra (1987).

Similarly, the nutrient contents in the leaf litter from the different tree species were found to vary between species and between months in the same species. An appraisal of the results revealed that, the total quantity of nitrogen added through litterfall was almost uniform in most of the tree species. Phosphorus content also showed a similar pattern. But the content of K in the litter varied considerably in different tree species. Annona and jack had lesser content of K (0.3 to 0.4 %), whereas the K contents of mahogany, bread fruit, mango, guava and bilimbi varied from 0.5 to 0.8 per cent. Ailanthus and cinnamon recorded a comparatively higher K content of 0.9 to 1.8 per cent.

In general, it was observed that the nutrient contents of the litter varied with tree species and season. The variation could be attributed to the differences in tissue longevity, species life forms and fertility of the sites (Pushp and Surendra, 1987; Sharma and Pande, 1989). The nutrient uptake capacity, the rooting pattern and the nutrient availability in the soil might have also contributed to this variation. If the nutrient status of the soil is low, the nutrient retranslocation during ageing and senescence of the leaves will be more, resulting in a lower nutrient content in leaf litter (Chapin *et al.*, 1980 ; Pushp and Surendra, 1987). According to Procter *et al.* (1985), the total nutrient return from different trees is more dependent on total litterfall than on the nutrient content of the litter. The present study is also in conformity with the above findings.

5.2.2. **Throughfall and stemflow**

In addition to litterfall, throughfall and stemflow are the other two avenues of nutrient addition in agroforestry system. Rain striking on plant surfaces, either drips to soil as throughfall or is channelled to the ground as stemflow.

The results of the study on throughfall and stemflow presented in Tables 12 to 30 revealed that considerable variation in the nutrient addtion by different tree species under study. Further, there was variation in nutrient addition among the different months also. In both throughfall and stemflow, maximum concentration of N, P and K was observed during March 1995. The reason for a generally high nutrient status in the month of March might be the absence of rain in the previous months. This might have permitted the accumulation of more nutrients and leaching down of the same from plant parts by the first pre-monsoon showers during the month of March and subsequent higher addition of nutrients. The above results are in conformity with the observations of Happy Mathew (1993), wherein maximum concentrations of nutrients in throughfall and stemflow were observed during April, with no rainfall during the months of January, February and March. The nutrient contents of throughfall and stemflow were the contributions from the dust matter deposited on the leaves by sedimentation (Charley and Richards, 1983). It was also observed that the variation in the nutrient contents of the throughfall of the same species was less when there was continuous rainy periods or the interval between the two rains was short. Duration of the rain was a primary factor affecting leaf leaching and subsequent nutrient addition (Turkey, 1970).

Variation was observed in the nutrient contents between species with respect to stemflow and throughfall. In the case of throughfall, maximum concentration of N and K was obtained in the case of breadfruit during March 1995, with a value of 56.45 and 131.7 ppm (Table 20). In the case of P, maximum concentration of 1.34 ppm was observed in jack during March 1995. The concentration of N was least in throughfall obtained from ailanthus (0.79 ppm) during October 1994, that of P in bread fruit (0.007 ppm) during October 1994 and that of K in jack (1.1 ppm) during July 1994.

Maximum N content (21.5 ppm) of stemflow was observed for wild jack during April 1994. The results also showed that in the case of ailanthus highest P content (0.486 ppm) and K content (49.86 ppm) were recorded during April 1995. The observed variation in the nutrient contents in stemflow in different trees might be due to the differences in species, tissue longevity and wettability of leaves (Turkey, 1970). Cole and Rapp (1980) reported that the variation in cycling rates between species is largely because of the inherent differences between species, relative to nutrient requirement and cycling strategies.

It was further noticed that there existed a variation between throughfall and stemflow in the same species. Generally, it was found that the throughfall water contained more nutrients than stemflow water. This is contradictory to the observations made by George (1979) and Baker and Attiwill (1987).

Among the nutrients in stemflow and throughfall, a higher amount was always observed for K followed by N and P. Experiments in some forest species carried out elsewhere have revealed that, the leachability was generally maximum for K (Eaton *et al.*, 1973; Wells *et al.*, 1975; Henderson *et al.*, 1977). Among the nutrients, the content of P was the lowest in throughfall and stemflow. This is in accordance with the findings of Wells *et al.* (1975) and Henderson *et al.* (1977). The higher contents of nitrogen and potassium in throughfall and stemflow might be due to the greater mobility of N and K as compared to P.

It is evident that between throughfall and stemflow, the former was the major source of nutrient input in the homestead (Table 41). The total nutrient input by throughfall in the homestead was 13.5715, 1.5683 and 28.4241 kg. of N, P and K respectively. The stemflow contributed only 0.5695 kg N, 0.0306 kg P and 0.9268 kg of K to the system. This is comparable with the values observed by Happy Mathew (1993). The reason for the lesser nutrient addition by stemflow might be due to the lower stem volume of the tree species as compared to their canopy volume. It could be logically expected to get higher values when the surface volume is higher. Besides, the nutrient content in stemflow was less than that of throughfall. As stated above, the total nutrient addition by throughfall and stemflow is a function of nutrient concentration and the total volume of tree species. Similar conclusions were made by Happy Mathew (1993) from a study in the southern zone of Kerala.

From the results discussed above, it could be concluded that the increase in proportion of plant cycling fraction of nutrients as a consequence of increased plant cover (both crops and trees) facilitated not only a reduction in the loss of nutrients but also enabled the various plants in the homestead to meet the requirements of highly mobile nutrients like potassium for their growth. The transport of nutrients below the rooting zone is a major reason for direct loss of nutrients in sedentary agriculture. The rate of this loss could be considerably reduced in homestead system, where the root exploitation

Table. 41 Nutrient addition by throughfall and stemflow from different species in the homestead

Tree / Crop species.	Nutrient addition by throughfall (kg)			Nutrient addition by stemflow (kg)		
	N	P	K	N	P	K
Jack	0.4905	0.0764	0.9315	0.0011	0.0005	0.0026
Ailanthus	0.4232	0.0506	0.6603	0.0054	0.0003	0.0111
Annona	0.1864	0.0091	0.4230	-	-	-
Wild jack	0.2718	0.0273	0.5660	0.0009	0.0000	0.0025
Bilimbi	0.2701	0.0122	0.7134	0.0008	0.0000	0.0016
Mahogany	0.0905	0.0102	0.1607	0.0005	0.0000	0.0008
Bread fruit	0.1684	0.0010	0.6593	-	-	-
Mango	0.0725	0.0008	0.1455	-	-	-
Guava	0.1345	0.0117	0.3323	-	-	-
Cinnamon	0.0655	0.0097	0.1181	0.0011	0.0000	0.0019
Pepper	0.2035	0.0028	0.3615	-	-	-
Coconut	11.1946	1.3566	23.3525	0.5597	0.0298	0.9063
Total	13.5715	1.5683	28.4241	0.5695	0.0306	0.9268

of soil would be larger and consequent reduction in the loss of nutrients. Moreover, the trees, by virtue of their deep roots, absorb nutrients from deeper unexploited soil layers and bring them to the soil surface by litter addition and through various plant cycling processes as discribed above.

5.2.3 Livestock and poultry

Yet another avenue of addition of nutrients in the homestead was manure obtained from livestock and poultry. Livestock and poultry added 38.21, 19.38 and 27.39 kg of N, P and K respectively. The main source of organic manure to the system was cowdung, followed by poultry manure. As a matter of fact, higher nutrient addition could naturally be expected from animals by supply of large quantities of these manures (Table 31). It was also found that the manures produced by livestock and poultry were used entirely for the crops by the farmer in the homestead as a result of which the farmer did not have to apply inorganic fertilizers to support the crop growth. Even under this condition, the farmer could maintain the fertility of the soil and productivity of crops. In addition to sustainability, because of organic farming practices, there was considerable saving in the expenditure for farm operations also.

5.3 Nutrient removal

Large quantities of nutrients were removed from the system through harvested produces (Table 32). The total amount of nutrients removed from the system was 23.04, 5.97 and 14.59 kg of N, P and K respectively. A major portion of the nutrient removal was through the harvest of coconut (14.35, 2.25 and 9.05 kg of N, P and K), followed by jack fruits (2.16 kg N, 0.6 kg P and 0.9 kg K) and cassava tubers (1.85 kg N, 0.8 kg P and 1.3 kg K). The high nutrient removal by coconut was due to the frequent harvest of nuts and the leaves. Under normal conditions, these harvests take place once in 45 days. On a per hectare basis, the nutrient removal by coconut was worked out to 35.45, 5.59 and 22.36 kg of N, P, and K respectively. These values are comparable with those obtained for Khanna and Nair (1977), who reported a nutrient removal of 33.1 kg N, 3.8 kg P and 13.4 kg K from one hectare of pure coconut plantation.

It was also noticed that the nutrient contents in the harvested produce varied with crops. This could be attributed to the differences in the chemical composition of crop species and the nature of the harvested produce. The nutrient removal by a particular species is a function of the quantum of harvestable material. In the present study, it was found that tuber crops removed more quantity of K. This was due to the higher K content of tubers. The N and K contents in the harvested produce of tubers were comparatively more than that of P.

Nutrient cycling processes that take place to varying degrees in all land use systems become particularly relevant in the homestead because of the likely effects of trees on such processes. "Closed" nutrient cycles are known to operate in mixed evergreen natural forests and homestead also presents a similar condition. The crown surface forms the boundary of the system where input of bioelements occurs through precipitation. The soil surface is the entry point of the inputs into the soil compartment (Nair, 1984). The conditions of the agroforestry home gardens are such that the loss of nutrients are comparatively low, because these are compensated by the addition of nutrients from other sources.

Nutrients taken up by plants are either stored in the increment (storage) compartments or are used for the production of the non-storage organs. Part of the nutrients that are taken up by plants are returned to the soil through two avenues. First, litterfall and secondly through the process of plant cycling. The latter represents that part of the total uptake of the nutrients which is again leached out from the vegetative parts through crown washout occurring as throughfall and stem flow. The major avenue of output of nutrients from the total system is "export" through harvested produce. In the case of woody perennials, it depends on the frequency and intensity of harvesting. But because even repeated harvests do not amount to destructive harvesting in woody perennials, the rates of the "export" in the homestead system are relatively low as compared to those in annual agricultural systems (Nair, 1984).

Table. 42 Addition, removal and net gain of nutrients in the homesteads

Nutrient cycling processes	Nutrients added (kg)		
	N	P	K
Litterfall	4.3543	1.1661	3.0231
Throughfall	13.5715	1.5683	28.4241
Stemflow	0.5695	0.0306	0.9268
Organic manure from livestock and poultry	38.2100	19.3800	27.3900
Nutrient removed by harvested produce	23.0400	5.9700	14.5900
Net gain	33.6653	16.1750	47.1740

An analysis of the nutrient cycling in the present homestead revealed that the quantity of nutrients added was much more than the nutrients removed. During the period of study, the homestead had a net gain of 33.6653, 16.1750 and 45.1740 kg of N, P and K respectively (Table 42). The mixed crop husbandry practices adopted and the presence of cattle/poultry in the homestead was the main reason for this. Litterfall and plant cycling mechanisms operative in the homestead also contributed to the net gain of nutrients. The role of multipurpose trees in the cycling of nutrients was specially noticed in this situation (Mitchell *et al.*, 1975; Nair, 1993).

5.4 Soil properties

5.4.1 Physical properties

The physical properties of the homestead soil were found to be better than those of the control (Table 33 & 34, Fig. 3 & 4). The moisture content in the homestead soil was higher than that of control. The frequent cultural operations, addition of substantial quantities of organic matter through farm yard manure and litterfall, facilitated higher moisture retention in the soil layers. Further, the shading effect of the trees reduced the soil evaporation. The lower soil temperature and the higher atmospheric humidity in the home garden, might have also contributed to the high soil moisture content.

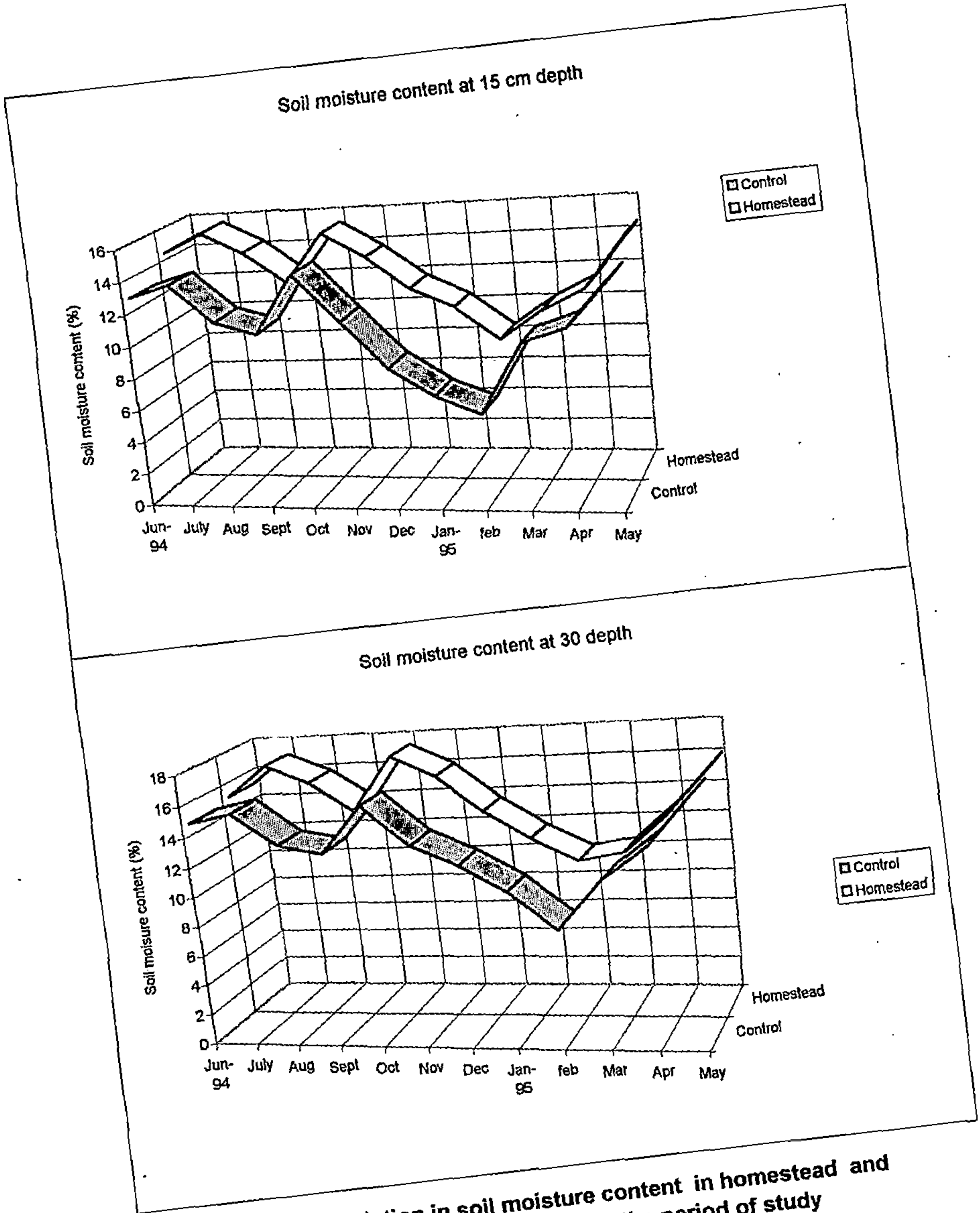


Fig. 3 Variation in soil moisture content in homestead and control at two depths during the period of study

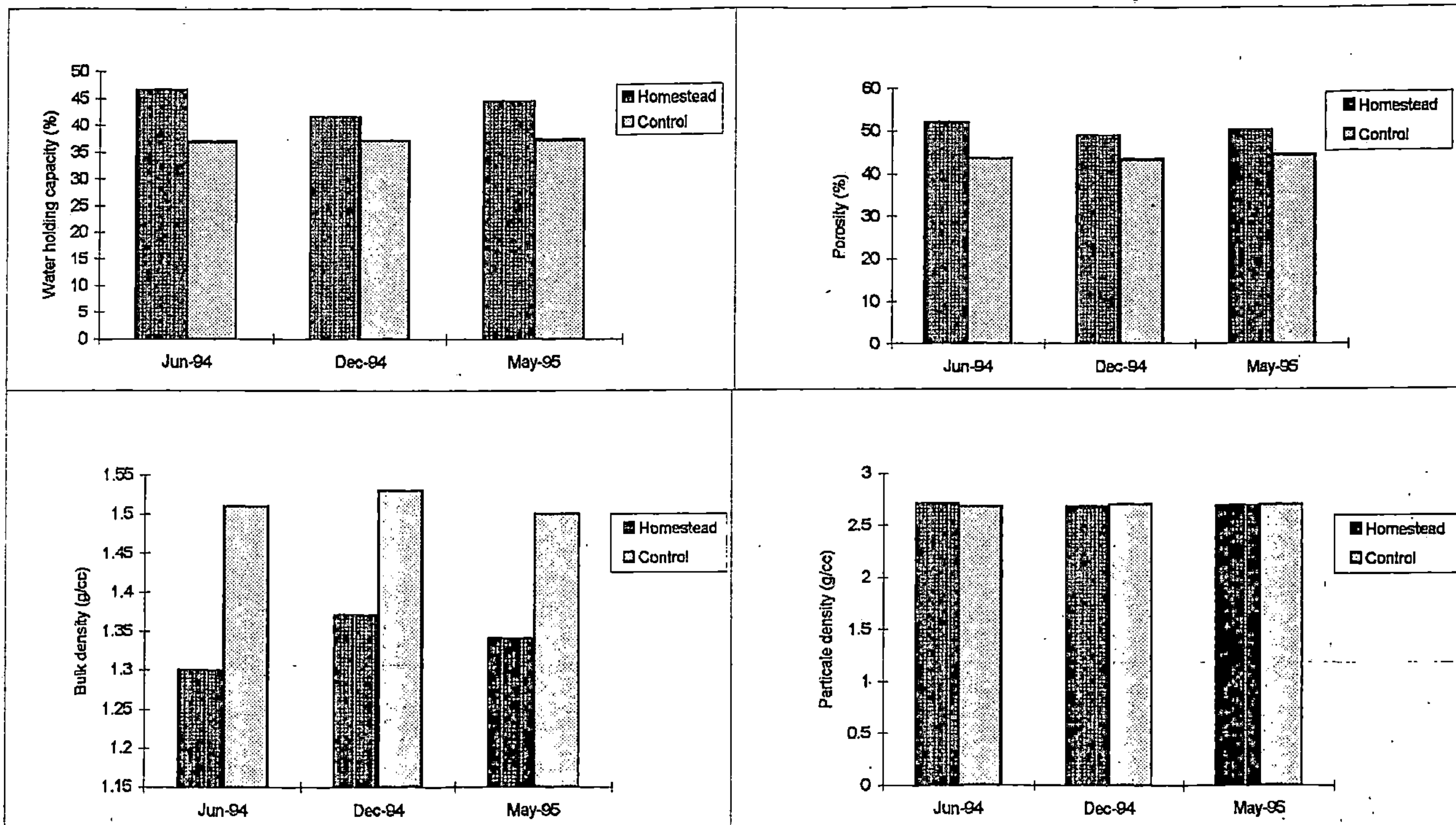


Fig. 4 Variation in soil physical properties of homestead and control during the period of study

The moisture content varied with the depth of the soil, both in the homestead and in the control. Higher moisture content was observed in the deeper layers. This could be attributed to the higher evaporation losses of water from the upper layers, since they are exposed to the action of external agencies like wind and sun.

The maximum water holding capacity and porosity were higher in the homestead soil when compared to the control (Table 34, Fig. 4). As discussed earlier, the higher content of organic carbon of the homestead may be the reason for this phenomenon. The effect of farm yard manure in increasing the water holding capacity and porosity of the soil has been reported by Pathak (1954); Salter *et al.* (1965); Biswas and Khosla (1971); Singh *et al.* (1976); Rajput and Sastry (1987b) and Happy Mathew *et al.* (1996).

The bulk density of the homestead soil was always lower than that of control. This was probably due to the addition of large quantities of organic matter in the homestead through litterfall and organic manures. The results are in conformity with the reports of Mazurak *et al.* (1975); Nambiar and Ghosh (1984) and Rajput and Sastry (1987b).

5.4.2 **Chemical properties.**

The fertility status of the homestead soil was substantially

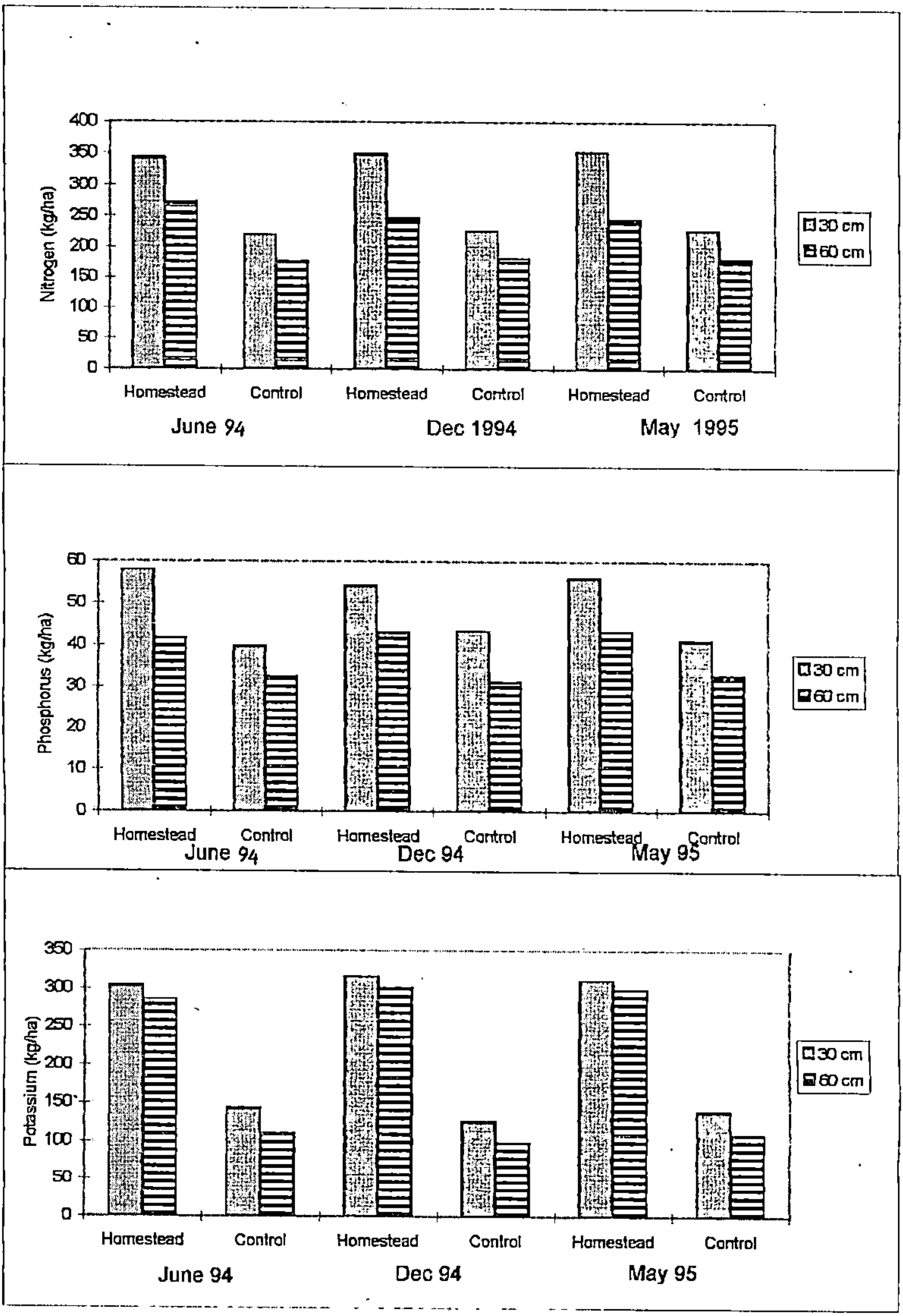


Fig. 5 Variation in soil nutrient content at two depths between the homestead and control during the period of study

higher than that in the control (Table 35, Fig. 5 & 6). The available N, P and K content in the homestead soil was much higher than that in the control. The variation was pronounced in top 0-30 cm deep soil layers (Fig.5). The higher nutrient status observed in the homestead soil might be due to the combined addition of organic manures and litterfall. Even though large quantities of nutrients were removed by way of harvest, still the higher value might be due to the return of nutrients back to the soil by various nutrient cycling processes (Happy Mathew, 1993). The results are also in conformity with the reports of Ovington *et al.* (1962); Switzer and Nelson (1972); Mitchell *et al.* (1975) and Fagerstorm and Lohm (1977). The role of trees in soil enrichment has been reported by Nair (1984) and Happy Mathew *et al.* (1996). The higher nutrient status of the top layers may be due to the addition of litter, stemflow, throughfall and organic manure to the top soil as reported by Happy Mathew (1993).

In the case of available potassium, the differences in the content of this element in the 0-30 cm and 30-60 cm layers were comparatively low as compared to those in other nutrients. This could be attributed to the mobile nature of potassium. Probably, the difference in the K content may be due to the luxury consumption of K by various crops in the homestead.

The organic carbon content was found to be more in the homestead soil (Table 35, Fig. 6). This could naturally be expected

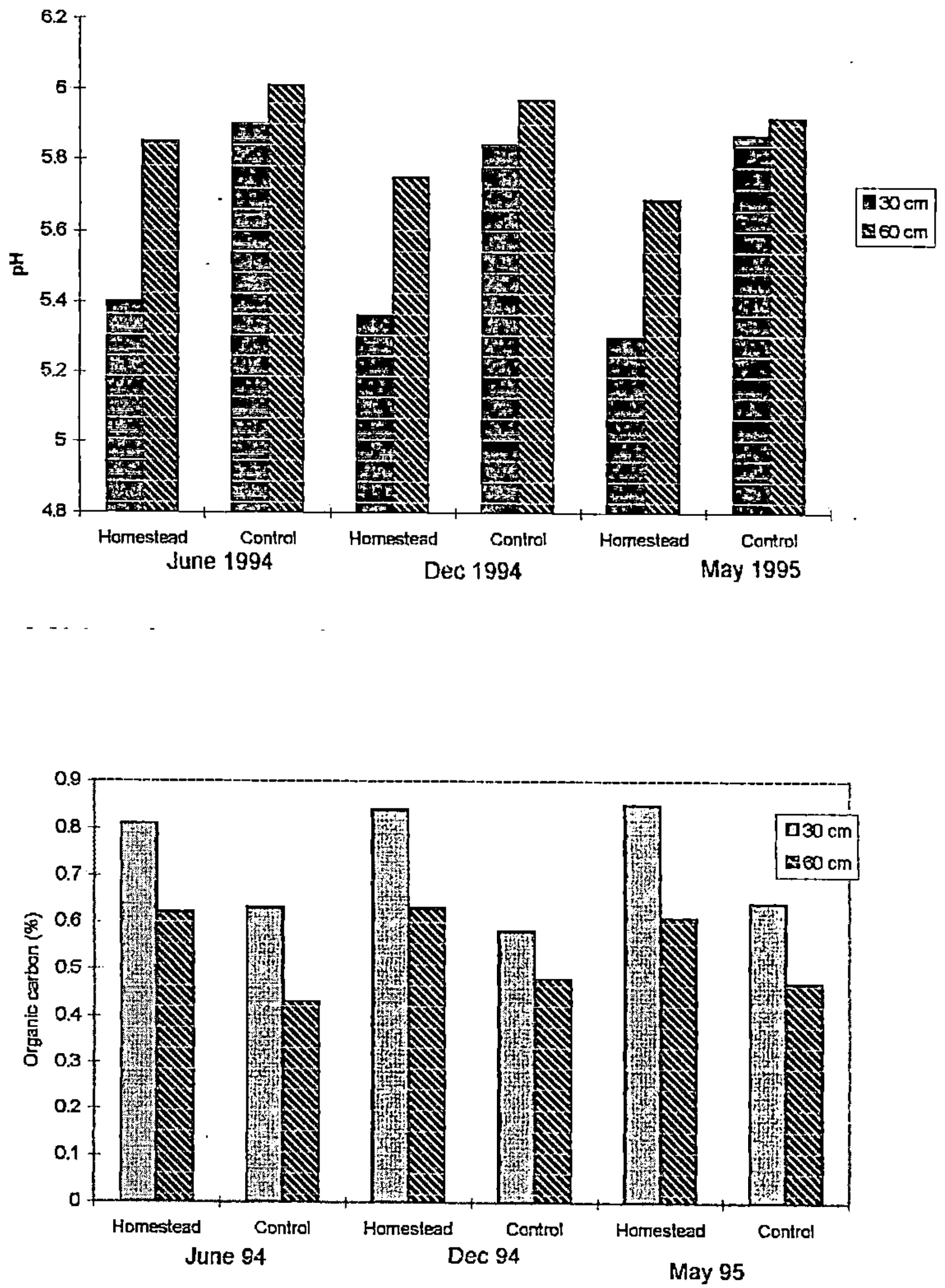


Fig. 6 Variation in soil pH and organic carbon content in the homestead and control at two depths during the period of study

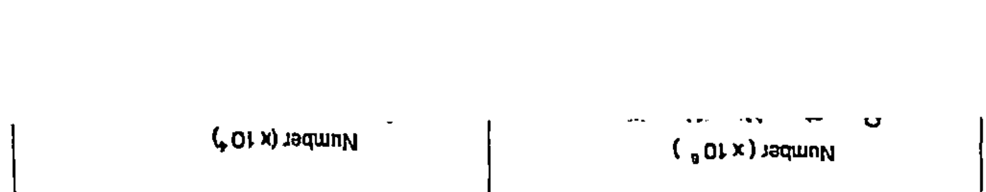
because of the higher litterfall and subsequent decomposition in the soil. This is in conformity with the findings of Rajput and Sastry (1987a).

The homestead soils generally had a lower pH than control. Higher organic matter addition followed by increased microbial activity and subsequent production of organic acids might have caused reduction in the soil reaction. Similar reports on the reduction in the soil reaction was made by Swaminathan (1987) and Lal (1989).

5.4.3 Microbial properties

It is evident from the study (Table 36, Fig. 7) that the population of all the micro-organisms studied, *viz.*, fungi, bacteria, actinomycetes and phosphate solubilising bacteria recorded a very high value in the homestead soil, as compared to control.

The higher microbial population observed might be due to the high intensity of cropping in the homestead and the addition of large quantities of organic matter from the crop residues. The effect of leaf fall in increasing the number of micro-organisms has been reported by Nair and Rao (1977) in an intensively cropped coconut-cocoa mixed plantation. The effect of organic matter in increasing the population of micro-organisms has also been reported by Potty (1977) and Gaur and Mukherjee (1980). The variation of the microbial population



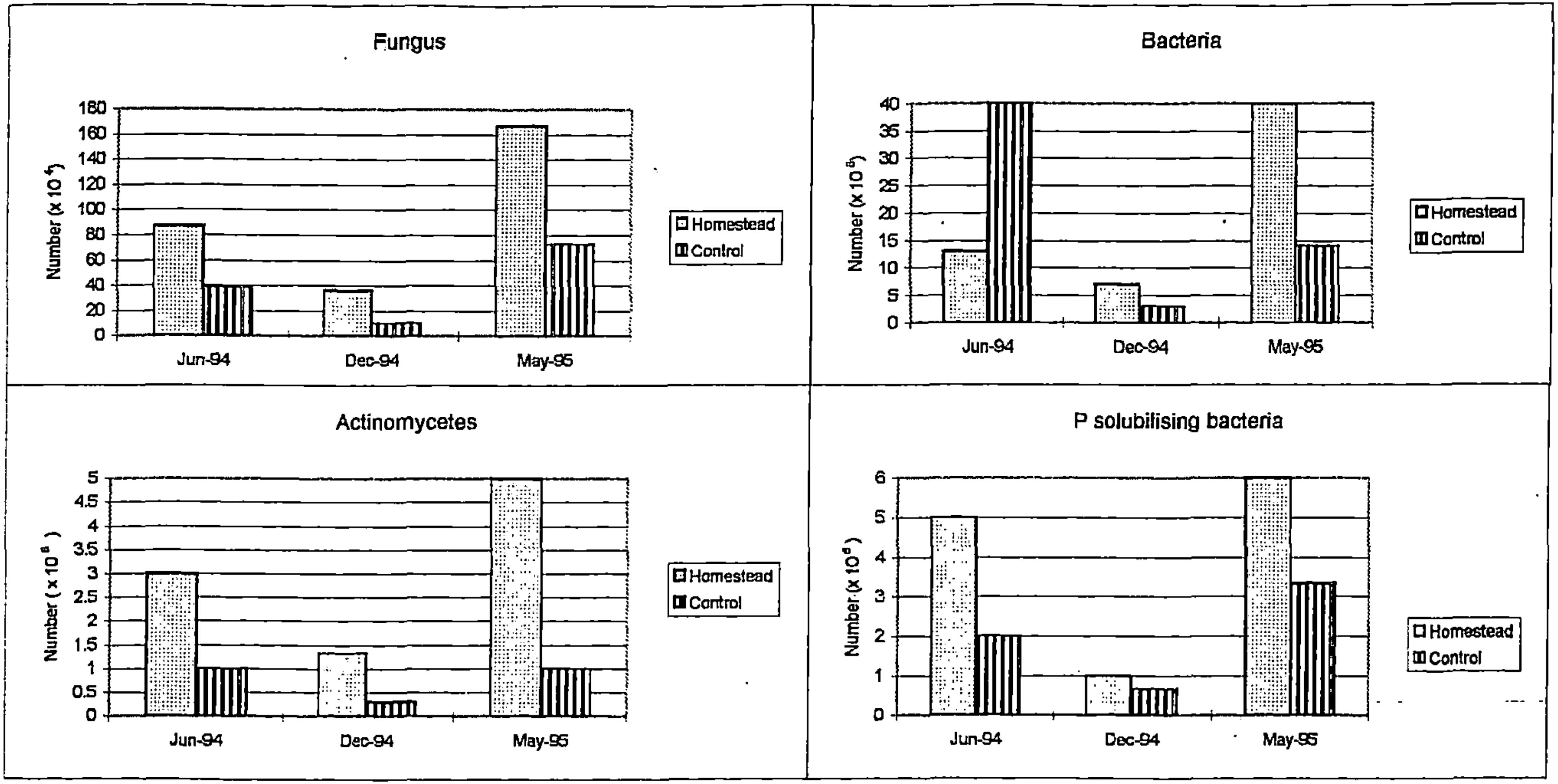


Fig.7 Variation in soil micro-organisms in the soil between the homestead and control during the period of study

observed at different seasons might be due to the differences in the moisture content, management practices, organic manures added and the type of crops grown in the homestead.

5.5 Microclimate

The mean monthly maximum temperature recorded in the homestead during the period under study ranged from 27.56^{0}C to 31.16^{0}C and minimum temperature ranged from 21.82^{0}C to 25.67^{0}C (Table 37). The values varied in accordance with the seasons. The total rainfall received during the period was 1681 mm. February was a rainless month and the maximum rainfall was obtained during May 1995. Unlike in the previous years, the onset of south-west monsoon was earlier than the normal period (which is considered to be unusual), and there was very heavy pre-monsoon showers, which resulted in comparatively higher amount of rainfall in the month of May 1995.

5.5.1 Relative humidity

Variation of relative humidity during different months, both in homestead and control, was noticed (Table 37, Fig. 8). During humid period of the year with high rainfall, the relative humidity was slightly higher in the open, while during the months of little or no rainfall, the homestead recorded a higher relative humidity. It was also noticed that the difference between the relative humidities in homestead and control was not much pronounced. Trees in the home garden acts as a

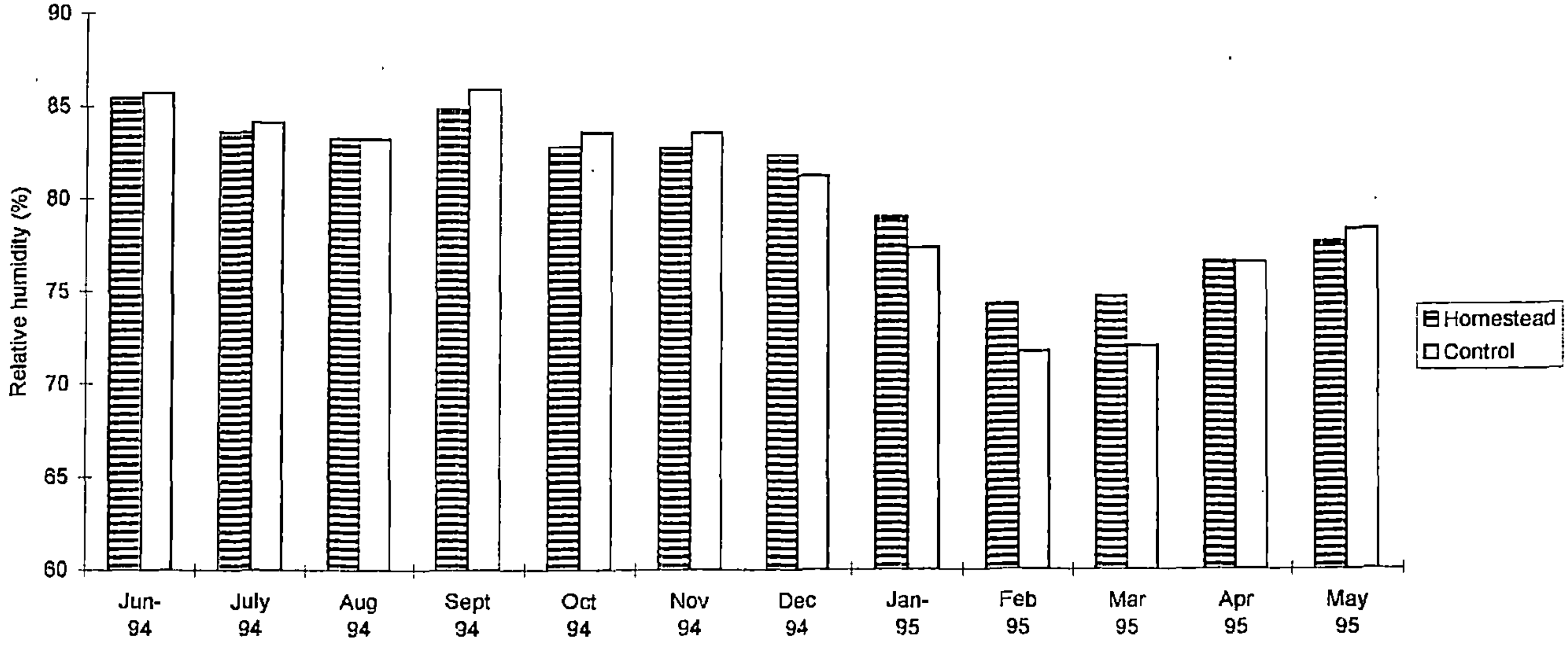


Fig. 8 Variation in relative humidity between homestead and control at different months during the period of study

buffer. The reduction of evaporation and transpiration, as a result of high humidity was reported by Balakrishnan (1977).

5.5.2 **Soil temperature**

The data on the variation in soil temperature (Table 37) revealed that the soil temperature was always lower in the homestead than in the open. This was true for the soil temperature recorded both at 15 cm and 30 cm depths (Fig. 9). The observed lower temperature in the homestead soil might be due to the crop cover on the ground and also due to the higher cropping intensity. Also, the canopy cover on the soil helped in reducing the exposure of the soil to the incidental solar radiation. This is in conformity with the reports of Nair and Balakrishnan (1977); Nair (1983) and Nair (1984). Monthly variation in the soil temperature was also observed. The maximum and minimum soil temperatures were almost identical to the maximum and minimum atmospheric temperature.

5.6 **Light intensity**

The results of the study on the light intensity under the canopies of major tree crops in comparison with the control revealed that the light intensity under the tree canopies was invariably less than that in the open (Table 38, Fig. 10). It was found that the maximum light infiltration was observed beneath coconut and the least in mahogany.

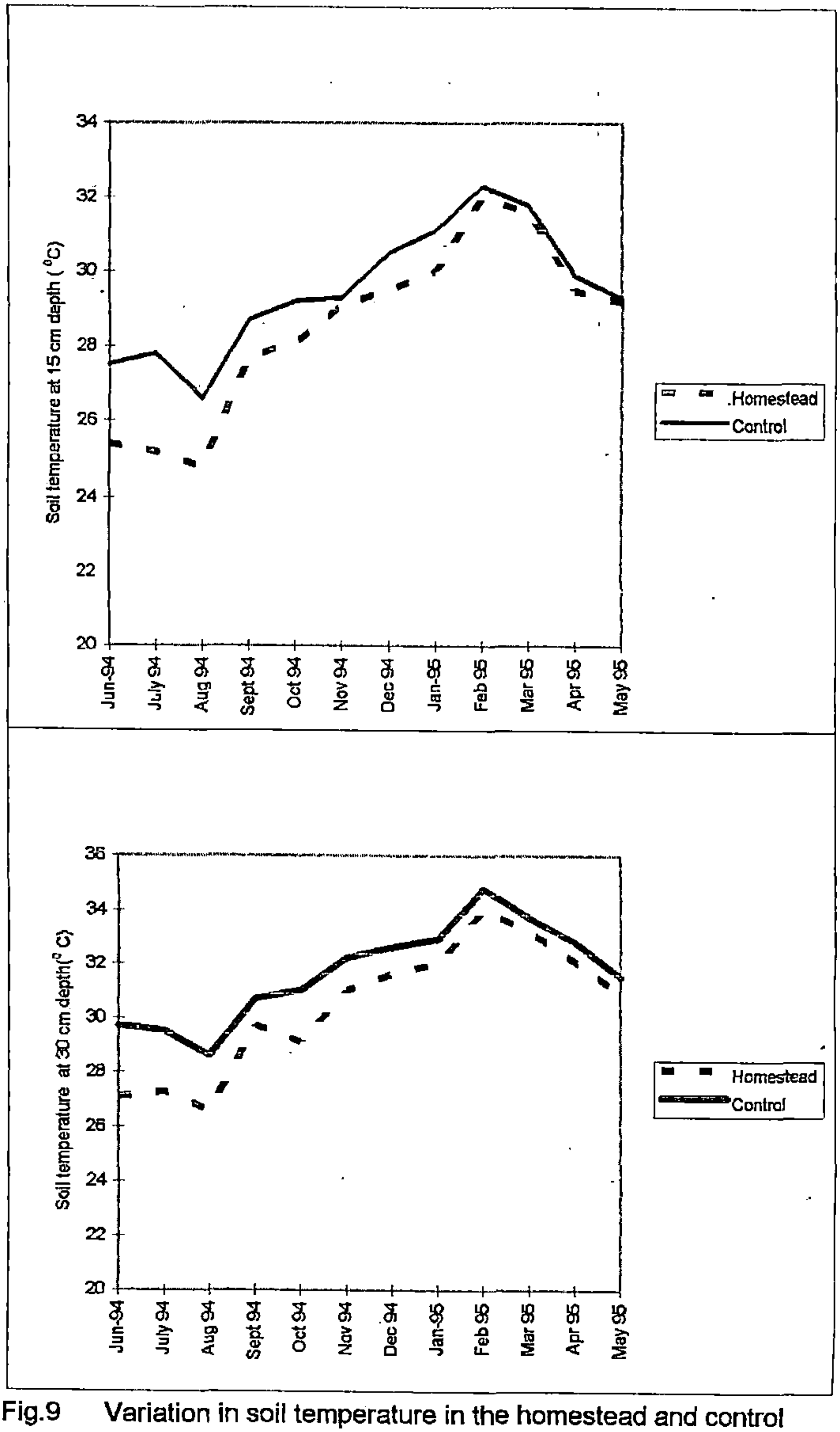


Fig.9 Variation in soil temperature in the homestead and control at two depths during the period of study

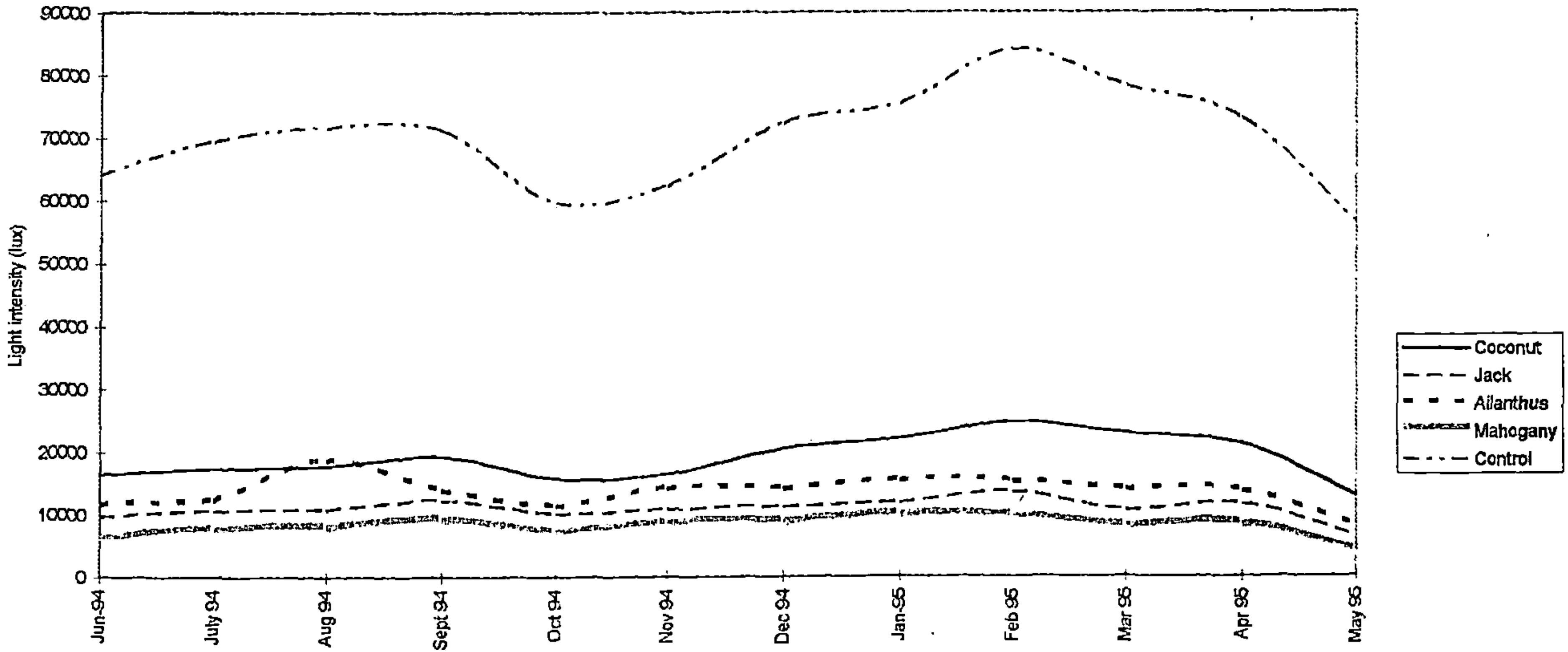


Fig. 10 Variation in the light intensity beneath different trees and control during the period of study

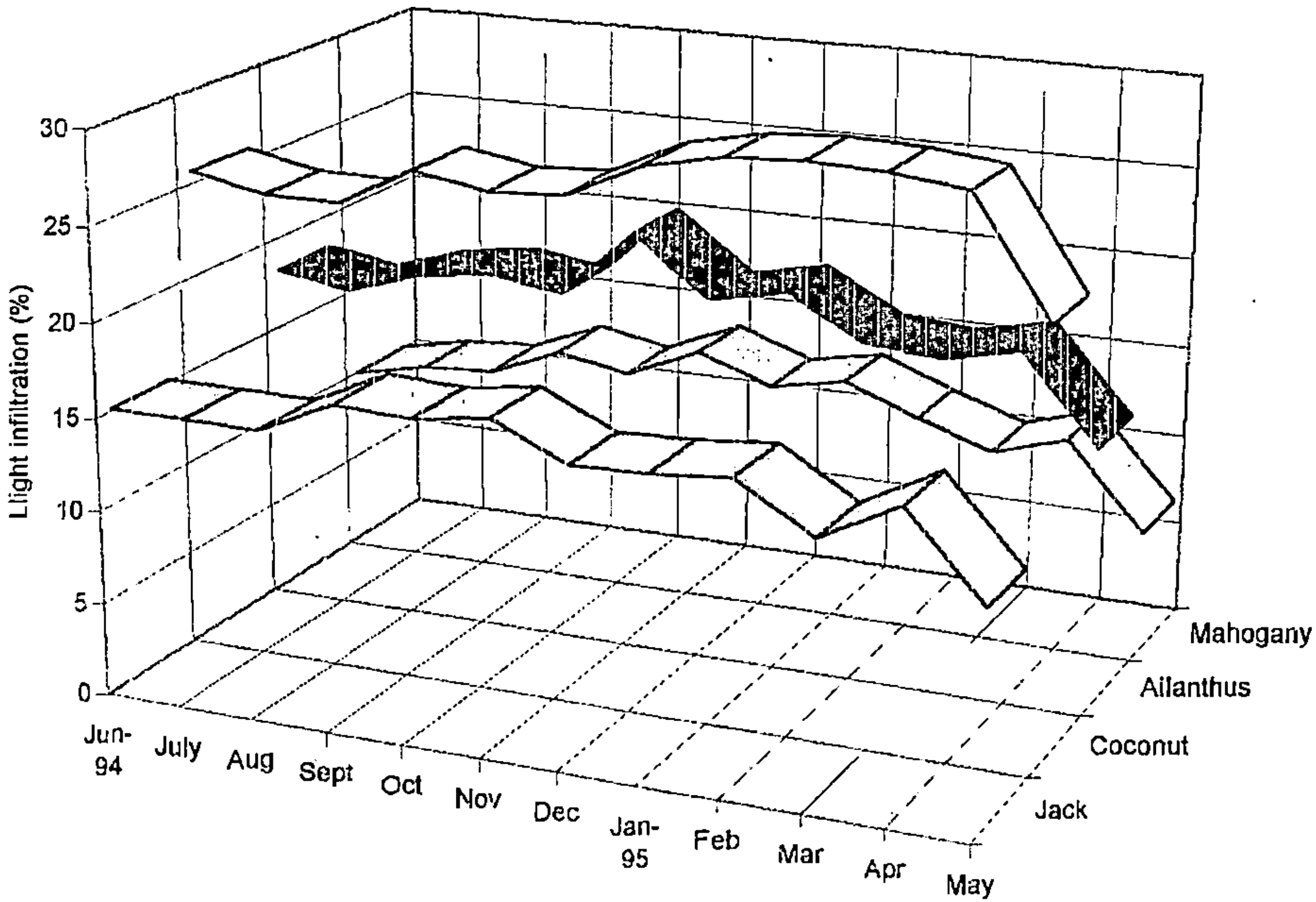


Fig . 11 Variation in the infiltration of light during the period of study under different tree

However, the percentage infiltration of solar radiation by different tree canopies, during different months of the year, remained almost constant. (Table 38, Fig. 11). The percentage of infiltration varied from 22.74 to 29.44, 11.37 to 17.34, 14.03 to 22.47 and 6.75 to 13.64 in the case of coconut, jack, ailanthus and mahogany respectively. As the light infiltration was less than 30 per cent of the total radiation, shade tolerant crops could be used for intercropping. Coconut, occupying the largest area, facilitated much more infiltration of light, making it possible for the growth of annual crops, requiring more light. Similar results in coconut based cropping system have been reported by Nair and Balakrishnan (1976); Nelliat *et al.* (1974) and Nair and Sreedharan (1986).

5.7 **Economic analysis**

Because of the presence of a variety of crops, and subsequent high cropping intensity, the homestead system not only maximised net returns, but also met the multiple demands of the farm family (Table 39). The study revealed that the net return was maximum from coconut. Among the individual enterprises, maximum benefit : cost ratio was obtained in the case of curry leaf. This might be due to the lesser investment and comparatively higher income obtained by selling the economic produces to the neighbours. It was seen that all perennial crops required a lower labour input, whereas, the expenses towards maintaining coconut was higher. In the present study, higher number of coconut trees, frequent harvests and intercultivation operations undertaken to coconut in the homestead resulted in higher expenditure. The labour requirement would be still higher under mixed cropping condition. This is in conformity with the findings of Nelliat and Krishnaji (1976), who reported higher labour requirement under mixed/multiple cropping with coconut in the south-western coast of Kerala.

Among the different enterprises, maximum amount was spent in maintaining the cow. By investing Rs. 8895/- , there was a net return of Rs. 3636/-. On scrutiny, the study also revealed that enterprise of cow utilised about 46 per cent of the total investment and generated almost 18 per cent of the net profit. Even though the income generation was not in proportion with the investment, it was important in view of the nutritional contribution to the homestead was concerned. The results are in conformity with the findings of Abdul Salam *et al.* (1991) who reported that the crop-livestock combination in the homesteads of Kerala interact synergistically, generate more income and maintain soil health.

The total annual investment to the system was Rs. 19312/- of which Rs. 5964/- (31 %) was spent towards labour charges. The higher labour requirement in mixed farming situation has been reported by Nelliat and Krishnaji (1970) and Nair (1979). The total labour requirements of the homestead were estimated to be 99.4 mandays, for which the farmer had paid an amount of Rs. 5964 /- during the period of study. By way of family labour, there was a saving of 84.5 mandays. Thus, an amount of Rs 5070 /- was saved by utilisation of family labour. Similar reports of financial savings in the homesteads by utilising family labour was reported by Nair (1979), Nair and Sreedharan (1986) and Abdul Salam *et al.* (1991).

The different farming activities of the homestead (26 enterprises) generated a net income of Rs 26469/ -. When the contribution by family labour was also considered, the net income from the system was enhanced to Rs. 31539/-.

The benefit : cost ratio of the homestead system was found to be 2.37. The high cropping intensity of 140 per cent with mixed farming was the reason for higher net return. A higher net return in homesteads with mixed farming has been reported by Nair (1976), Abdul Salam *et al.* (1991), Abdul Salam *et al.* (1992 b) and Happy Mathew *et al.* (1996).

The higher benefit : cost ratio of 2.37 in the experimental homestead as compared to 1.64 as reported by Abdul Salam *et al.* (1991) in a homestead in the coastal uplands of Kerala with mixed farming system might be due to the efficient utilization of time, space and resources in the present study.

The system, in general, was found to be sustainable and profitable, by supplying food, fuel, fodder and manure which ensured regular cash flow and family labour utilisation. The enterprise diversification was a deliberate strategy aimed at producing harvests throughout the year. There was always some product of economic value available for household use or sale along with tree-crop-livestock integration.

SUMMARY

SUMMARY

A study was undertaken in a homestead of 0.4840 hectare in Thiruvananthapuram district of southern Kerala, for a period of one year from June 1994 to May 1995. The study consisted of the inventory of the homestead, the nutrient cycling by different tree species, the role of various biological components on the soil physical, chemical and biological properties, their influence on the microclimate in the homestead and the overall economics of the system.

The homestead was inhabited by a family of seven members. The homestead was a coconut-based mixed farming system. It consisted of 26 tree/crop components in addition to a cow and its calf, two goats and their kids, and 23 poultry birds. The other tree components were jack, mahogany, ailanthus, annona, papaya, mango, guava, cinnamon, bread fruit, wild jack, and bilimbi. Crop diversification was achieved through intercropping in the interspaces of tree species, resulting in a cropping intensity of 140 per cent. The major intercrops cultivated were cassava, banana, amorphophallus, colocasia, ginger, turmeric, drumstick, chekurmanis and curry leaf.

The summary of results of the experiment are given below.

1. The crop canopies of the tree/crop components occupied different vertical layers and thereby maximum space utilization and solar energy harvesting were achieved in the homestead.

2. Ten tree components of the homestead produced 384.64 kg. litter on dry weight basis which resulted in an annual addition of 4.3543, 1.1661 and 3.0231 kg of N, P and K, respectively in the homestead soil.

3. Throughfall was the major nutrient cycling process which recycled 13.5715 kg N, 1.5683 kg P and 28.4241 kg K to the homestead.

4. The nutrient addition by stemflow was comparatively less and amounted to 0.5695 kg. N, 0.0306 kg. P and 0.9268 kg. K in the homestead.

5. The quantities of nutrients added by organic manure obtained from livestock and poultry components were 38.21, 19.38 and 27.39 kg of N, P and K, respectively.

6. The produce harvested from different tree / crop components resulted in the removal of 23.04, 5.97 and 14.59 kg. of N, P and K, respectively.

7. The moisture content, maximum water holding capacity and porosity of the homestead soil was more than that of the control. However, bulk density of the homestead soil was found to be less than that of the control.

8. The available N, P and K content of the homestead was found to have higher values than those in the open. The soil pH was slightly lower in the homestead soil.

9. The populations of fungi, actinomycetes and bacteria including P solubilising bacteria were found to be very high in homestead soil. Seasonal variation in the population of micro-organisms was also noticed.

10. Relative humidity was slightly lower in the homestead during the rainy months but it recorded a slightly higher value in the homestead during the summer months.

11. The soil temperature of the homestead was always less than that in the control.

12. Light available at the base of the different trees in the homegarden was invariably less than that in the open. The maximum light

penetration was noticed at the base of coconut and the least in mahogany.

13. The economic analysis of the homestead revealed that by investing Rs. 19312/-, the farmer received a gross return of Rs. 45781/- which resulted in a net profit of Rs.26469/- and benefit : cost ratio of 2.37. The family labour provided a net saving of Rs. 5070/-.

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APPENDICES

APPENDIX I

Scientific names of the crops present in the homestead

Sl. No	Common Name	Scientific name
1	Coconut	*Cocos nucifera*
2	Banana	*Musa sp.*
3	Tapioca (Cassava)	*Manihot esculenta*
4	Amorphophallus	*Amorphophallus companulatus*
5	Pepper	*Piper nigrum*
6	Erythrina	*Erythrina indica*
7	Colocasia	*Colocasia esculenta*
8	Ginger	*Zingiber officinale*
9	Turmeric	*Curcuma longa*
10	Curry leaf	*Murraya koenigi*
11	Drumstick	*Moringa oleifera*
12	Chekurmanis	*Psoropus androgayanum*
13	Breadfruit	*Artocarpus altilis*
14	Jack	*Artocarpus heterophyllus*
15	Mango	*Mangifera indica*
16	Goava	*Psidium guajava*
17	Papaya	*Carica papaya*
18	Wild jack	*Artocarpus hirsuta*
19	Cinnamon	*Cinnamomum zeylanicum*
20	Ailanthus	*Ailanthus tryphysa*
21	Mahogany	*Swietania macrophylla*
22	Rose apple	*Eugenea jambolana*
23	Annona	*Annona squamosa*
24	Bilimbi	*Averrohoea bilimbi*
25	Amaranthus	*Amaranthus sp*
26	Bhindi	*Abelmoscus esculentus*
27	Tomato	*Lycopersicum esculantum*
28	Brinjal	*Solanum melongena*
29	Bittergourd	*Momordica charantia*
30	Snakegourd	*Trichosanthus anguina*
31	Cowpea	*Vigna unguiculata*

ABSTRACT

NUTRIENT CYCLING AND SOIL PRODUCTIVITY STUDIES OF HOMESTEAD AGROFORESTRY SYSTEMS OF SOUTHERN KERALA

By

JOISE ABRAHAM

ABSTRACT OF THESIS
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ABSTRACT

A study was undertaken to investigate on the nutrient dynamics and soil productivity aspects of a 0.48 ha size homestead in Thiruvananthapuram district of southern Kerala for a period of one year from June 1994 to May 1995.

The experimental homestead was a coconut-based one, inhabited by a family of seven members. Apart from coconut, other tree components in the homestead were jack, ailanthus, mahogany, wild jack, mango, papaya, annona, guava, rose apple, bilimbi and cinnamon. These trees were intercropped with annual crops like banana, cassava, amorphophallus, colocasia, ginger, turmeric and vegetables. The homestead had a cropping intensity of 140 per cent. Animal components of the homestead included a cow and its calf, two goats and their lambs and 23 poultry birds.

The study revealed that the nutrient addition by litterfall and plant cycling (which includes throughfall and stemflow) in the homestead resulted in the addition of large quantity of nutrients to the soil. The annual litter addition to the homestead from different trees amounted to 384.64 kg, with a nutrient input of 4.3543, 1.1661 and 3.0231 kg of N, P and K respectively. Nutrient addition by throughfall accounted to 13.5715, 1.5683 and 28.4241 kg and that of

stemflow was estimated to be 0.5695, 0.0306 and 0.9268 kg of N, P and K respectively. Livestock and poultry added 38.21, 19.38 and 27.39 kg of N, P and K respectively to the homestead. The harvested produce of different crops removed 23.04 kg N, 5.97 kg P and 14.59 kg K from the homestead. During the period of study the homestead had a net nutrient gain of 33.6653, 16.1750 and 45.1740 kg of N, P and K respectively.

Studies on the soil physical, chemical and biological properties of the homestead showed a favourable edge over the control. Lesser soil temperature, low bulk density, higher available nutrient status, higher organic carbon content, lesser pH and higher microbial population were observed in the homestead soil than that in the control.

Light intensity in the homestead was found to be less than 30% of that in control, beneath all of the major tree species. Economic analysis of the homestead showed that the farmer could generate a gross income of Rs. 45781/- by investing an amount of Rs. 19312. The overall benefit: cost ratio of the homestead was found to be 2.37. The system, in general, was found to be profitable and sustainable.