STATISTICAL MODELS FOR PROFIT MAXIMIZATION OF HOMESTEADS IN KERALA

by

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THESIS

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DECLARATION

I, hereby declare that this thesis entitled **"Statistical models for profit maximization of homesteads in Kerala"** is a bonafide record of research work done by me during the course of research and the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title, of any other University or Society.

01/08/17

Place :Vellayani
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Certified that this thesis entitled **"Statistical models for profit maximization of homesteads in Kerala"** is a record of research work done independently by Mr. Muhammed Jaslam, P. K., under my guidance and supervision and that it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

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MUHAMMED JASLAM P K

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LIST OF ABBREVIATIONS AND SYMBOLS USED

AEUs	Agro Ecological Units
AEU8	Southern laterites
AEU9	South central laterites
Avg.	Average
B.C	Benefit Cost
Fig.	Figure
GDP	Gross Domestic Product
ha	Hectares
HFS	Homestead Farming System
i.e	that is
LP	Linear Programming
Max	Maximum
Min	Minimum
NSSO	National Sample Survey Office
S_1	Crop only
S_2	Crop with poultry and goat
S_3	Crop with poultry, goat and cattle
RH	Right Hand
Viz	Namely
%	Per cent
₹, Rs	Rupees
et al.	Co-workers

Introduction

CHAPTER I

INTRODUCTION

Agriculture is the backbone of Indian economy, with 17.01 per cent contribution to the Gross Domestic Product (GDP) of the nation and more significantly as per the National Sample Survey Office (NSSO) in 2011–12, the share of agriculture in employment was 48.9 per cent. This indicates the very low productivity per person engaged in agriculture as compared to other sectors. As a result, during 2012-13 period, an average Indian farmer's monthly income was estimated at Rs 6,426/-, which is not satisfactory for the better livelihood (Gulathi and Saini, 2016). Going by the available evidence, recent growth record of agriculture has also been not satisfactory. As against the Twelfth Five Year Plan's (2012–17) objective of 4 per cent growth for the agriculture and allied sectors, the growth recorded was 4.2 per cent in 2013-14, -0.2 per cent in 2014–15, and 1.1 per cent in 2015–16 (GOI, 2016)

Kerala has high population density. Out of a total geographical area of 38.85 lakh hectares, total cropped area is about 56 per cent and the average size of land holding in Kerala is 0.27 hectare and nearly 50 per cent of the land holding size below one hectare (holdings belong to the marginal farmers). There is virtually no scope for increasing the area under cultivation, owing to rapid urbanization and industrialization. Given the land constraint and resultant domination of families with marginal or small landholdings, and the farmer's strategy is not to maximize the production of a solo crop but to grow tiers of several crops on the same piece of land. This has given rise to home gardening (also called homestead cultivation) as a common farming practice among the small and marginal framers who dominate Kerala's agriculture. The beginning of home gardening is founded from South East Asia and East Africa. In Java (Indonesia) and Kerala (India), home gardening is a way of life and even now critical to local subsistence economy and food security (Nair and Kumar, 2006). The home gardens of Kerala evolved because of the pressure of shrinking land resource base joined with a high population density, which necessitated a conscious attempt on the part of farmers to achieve their goals which could be economically viable and ecologically sustainable while contributing towards food security of the state.

Homestead cultivation in brief is the cultivation around the immediate surroundings of a house. Though numerous definitions are available, John (1997) comprehensively defined homestead/ home garden as a functional/operative and self-sustaining farm unit which consists of a conglomeration of crops and multipurpose trees, planted arbitrarily, with or without animals/poultry/ apiculture, owned and primarily managed by the dwelling farm family, with the objectives of satisfying the basic family needs (food, fuel, timber) and producing marketable surplus for the purchase of non-producible items.

However, the conventional home gardens were handled irrationally without any planning and with very low resource use efficiency. Though Kerala used to be an agrarian state; Agriculture has ceased to be the most important economic activity. The Situation Assessment Survey of Agricultural Households conducted at national level in NSSO 70th round (January-December 2013) revealed that Kerala had the least percentage share of agricultural households in the country i.e.; 27.3 per cent and nearly, 61 per cent of the agricultural households reported to have earned income from activities other than agricultural activities. Mere 16 per cent reported cultivation as foremost source of income and 0.6 per cent reported livestock as chief source of income.

In traditional agriculture, few inefficient allocations of resources were reported (Haque, 2006). Increasing farm inputs cost, volatile prices and resultant decline in profitability has been making agriculture a loosing proposition. Increasing population and low per capita availability of lands have necessitated better management practices in home gardens. Evidences from various parts revealed that homestead farming and interventions in home gardens could play a considerable role in improving food security particularly for the resource poor rural households in developing countries.

The Kerala state has been delineated in to 23 Agro Ecological Units (AEUs) by the National Bureau of Soil Survey and Land Use planning, Bangalore (2012) based on climatic conditions and nature of soil, which is most ideal for formulating any policy or programme to improve location specific cropping system across the state (Kurian, 2012). It is essential to prepare strategies and action plan for each AEU for the development of agriculture and allied sectors. Each district has been divided into agro-ecological units on panchayath basis within the overall framework of technical parameters. The yield gaps as well as the potential and issues in AEU have to be addressed separately considering the socio-economic setting. There are several region-specific gaps which limit the opportunity of realizing higher yield of the crops/livestock/fish potential. Future crop yields and food security may hinge on the ability of farmers to narrow the gap between the current yields and yield potential ceilings. The district level yield gaps for various crops, technology adoption index for various practices, occurrence of pests and diseases, soil fertility, constraints like labour availability, marketing, mechanization, irrigation and researchable issues are to be addressed on AEU-wise for the growth and development of agriculture in the state.

In agriculture, like in any other business, the efficiency is accomplished by an optimum utilization of resources. Resources include land, labour, capital, etc.. Optimum allocation of land and other resources involves decisions regarding what crops to produce, how much land to allot to each crop activity and what strategy and combination of inputs to each crop so that the farm return is maximum. In this perspective, it is necessary that the available scarce resources should be used economically and efficiently. The efficiency of farming depends on such combination of inputs that is most economical to secure a given output. The efficiency of given resources is said to be greater when higher the output for unit input and conversely greater the efficiency of resources when lower the input per unit of output. The maximization of efficiency is therefore a criterion for maximizing the profit. Relating to this, according to Hassan *et al.* (2015) the only way to meet increasing demand of food, fibre and fuel for the ever increasing population is by increasing production per unit area which is possible by more scientific utilization of the resources and their optimal allocation to achieve maximum returns.

Mathematical programming tools have been employed to model mixed farming, horticultural crops, and livestock alone, various breeds and varieties, and all sorts of combinations of different activities in homesteads (Mehta, 1992). Mathematical programming, also known as mathematical optimization model, is the selection of a best element (with regard to some criterion) from some set of available alternatives. Optimization is the act of achieving the best possible result under given circumstances. The goal of all such decisions is either to minimize effort or to maximize benefit. The effort or the benefit can be usually expressed as a function of certain design variables. Hence, optimization is the process of finding the conditions that give the maximum or the minimum value of a function.

In this context, the present study is an attempt to analyze the possibilities and prospects of increasing farm profitability by rational resource allocation through the application of Statistical modeling that enhances sustainable production of homesteads.

1.1 SPECIFIC OBJECTIVES OF THE STUDY

1. To examine the existing cropping pattern of homesteads in Kerala
2. To analyze the farm income and benefit cost analysis in different holding size and different cropping/farming pattern.
3. To develop suitable statistical models for the existing cropping system model that maximizes production by the optimal use of available resources.

1.2 SCOPE OF THE STUDY

The finding of the study would be very much useful to suggest optimal homestead model for efficient use the scarce resources resulting enhancement of net returns over existing plan even after considering requirements of homestead farmers of the study area. The study also will throw lights on future potentialities of increasing net returns under different cropping/farming systems.

1.3 LIMITATION OF THE STUDY

The study was conducted in a limited period of time, in a limited area of particular agro ecological and socio economic situation and obviously suffers from draw-backs and any generalization of the results could not be wholly unbiased. The necessary primary data were collected from the farmers based on their recall memory by interview method and hence was inherent limitation.

1.4 PLAN OF THE THESIS

This thesis is presented in five chapters. The first chapter is devoted to the introduction of the problem, objectives and scope of the study. The second chapter attempts a critical review of past work done. The third chapter deals with sampling design, method of collection of data and description of the analytical tools. The fourth chapter presents the analysis of the results and discussion. The last chapter throws light on the summary and conclusion emerged from the study.

Review of Literature

CHAPTER II

REVIEW OF LITERATURE

For any investigation, the findings of earlier studies may possibly give indications to the problems and provide guidelines for the present study. In addition, the earlier studies provide the lacunae in the existing information and form the basis for formulating new studies. In this chapter, an attempt is made to critically review the literature of the past research work relevant to the present study. The research work carried out by various research workers related to the problem under study has been reviewed under the following heads.

2.1 Characteristics of existing homesteads

2.2 Importance of linear programming technique

2.3 Application of linear programming in agriculture and farming system modeling.

2.1 CHARACTERISTICS OF EXISTING HOMESTEADS

Homesteads symbolize a crucial day-to-day survival strategy consisting of primary (plant) and secondary (animal) food production for household consumption, in addition to generating small amounts of income in cash or kind through the sale or trade of surplus production. Homestead production has major impact on food and nutritional security of households as per several studies. Nutritive food in large amount was found supplied often by homesteads from relatively small extensions of land unsuited for field agriculture (Ninez, 1984).

Homesteads in Kerala are assumed to be around 4000 years old. As a tactic approach to stabilize their household food security and income against the risks and uncertainties of mono-cropping, the small and marginal farmers of Kerala depend on homesteads (Jose and Shanmugarathnam, 1993).

According to Kumar *et al.* (1994), homesteads have been described as operational farm units which integrate trees with field crops, livestock, poultry and or fish, with the fundamental intention of ensuring persistent accessibility of multiple products such as food, vegetables, fruits, fodder, fuel, timber, medicines and/or ornamentals, along with generating employment and income.

Predominance of fruit trees and food-producing (not specifically fruit-producing) trees is an evident feature of the tree-crop element of homesteads. According to John (1997), in southern Kerala a major portion of the homesteads upper canopy was above 25 m in height, includes coconut, fruit trees, arecanut, and tree for timber purpose, followed by medium-sized fruit, spice and fuel trees, rising to a height of 10–20 m. The third layer includes crops like pepper, tree spices, and fruit trees mounting to a height of 3–10 m. The lowest layer was occupied by banana, cassava and other tuber crops which grow between 1–3 m in height. Pineapple, vegetables, and other herbaceous crops were grown at the ground level.

Homestead farming is more safe and sound than monoculture by virtue of diversification. Homestead farmers avoid economic risks, and are less susceptible to radical price fluctuations connected with changes in supply and demand by raising a variety of crops. The number of crop and tree species in homesteads varied from less than 5 to more than 40 as per the study conducted by John (1997) on 400 homesteads in Thiruvananthapuram district of Kerala. Majority of the home gardens (57.75 %) consisted of 10–20 species with an average of 14–15 species and 397 plants per homestead were recorded in the region as a total, projecting a very high degree of crop combination and diversification. An account on different crop categories showing that tuber crops ranked first in the region, followed by fruits, oil-yielding palms (such as coconut), rubber, spices, vegetables, trees used for timber and fodder crops.

A further assessment of the diversification implemented by farmers in their homesteads showed that cattle-rearing was a complementary enterprise in 17.5 per cent of homesteads and poultry in 30.25 per cent along with crops. 30.5 per cent of homesteads owned cattle, goats, sheep and poultry (chicken, duck, quail, and turkey) (Jacob and Nair, 1999).

According to Kumar and Nair (2004), tropical homesteads are one among the oldest form of land-use systems which are measured to be an essence of sustainability. Studies on homesteads during the past 25 years by them revealed that the major factors contributing to the sustainability of these systems were in terms of biophysical benefits *viz.*, efficient nutrient cycling by multispecies composition, preservation of bio-cultural diversity, product diversification in addition to nonmarket values of products and services, and social and cultural principles together with the prospect for gender equality in organizing the systems.

With the rising prominence on industrial models of agricultural growth, fragmentation of land holdings due to demographic pressures, negligence of traditional values, concerns were raised about the future of homesteads, but such concerns seemed to be groundless. As obvious from the ancient Indian epics *Ramayana* and *Mahabharata*, homesteads have been a manner of life for the households in India for centuries, where the epics consist of a description of '*Ashok Vatika*', a type of today's homestead (Puri and Nair, 2004).

Homestead cultivation can be simply meant as cultivation around the direct surroundings of a house which has developed through generations of gradual increase of crop cultivation with respect to two prime attributes *viz.*, rising human demands and the scarcity of arable land. Homesteads across the world reveal some basic facts such as they characterize a multi-storey combination of a variety of trees and crops in alliance with domestic animals in and around the home. In accordance with the reports, these homesteads were recognized by diverse names such as home gardens, household or homestead farms, agro-forestry home gardens, backyard gardens, compound farms, dooryard gardens, village forest gardens, and house gardens (Kumar and Nair, 2004). Homesteads were also defined as mixed gardens, farmyard enterprises, kitchen gardens and traditional food production system at the household level (Ali, 2005).

Wiersum (2006) stated that, in developing countries all around the world, traditional homesteads have been found as a vital element of family farming, confined food system and agricultural landscape which clearly indicate that the loss of homestead has a direct impact on the nutritional security of poor households, since their income is deficient to meet whole household consumption expenditure.

Krishnankutty *et al.* (2013) conducted studies on the future of homestead farming system by surveying and analyzing the occupational category of the heads of households besides the temporal variations in region under individual homesteads among a sample of 150 coconut based homesteads. Margalef index for species richness under the surveyed homesteads was observed in the range of 0.31 to 1.85 which is substantial when compared to average holding size of less than 0.1ha. The Shannon–Weiner index intended for evenness ranged between 0.15-2.00 which translates to heterogeneity in extent of species in various homesteads.

According to the reports obtained from studies conducted by Helen and Baby (2013) on diversifications in coconut based small homesteads of Kerala, farmers solely depending on farming alone were found suffering with little and fluctuating income. Maintenance of integrated farming system in coconut based homesteads was found difficult with many obstacles. The socio economic development within the farming community in the aspects of improved literacy level and foreign earned money by family members led to withdrawing from labour intensive enterprises, livestock components in particular.

According to Babu (2014), farmers favored intercrops and allied enterprises with fewer management practices and fewer labour demanding activities in spite of knowing the fact that major income contribution was from dairy farming. More emphasized research and development efforts need to be implied intensively on the socio-economic aspects of farmers under different agro-ecological situations in the country, to renew the existing state of coconut based homesteads so as to sustain the coconut based homesteads. This exhibits the urge to demonstrate the economic feasibility of the successful grouping of enterprises in homesteads appropriate to the specific micro farming conditions so that farmers can easily adopt the required models.

Homestead production needs to be encouraged since it is considered to be a subsystem under agricultural system that can produce items for household consumption that are not affordable through agriculture. Homestead, being an independent equipped unit, raising a number of crops along with rearing of livestock, poultry or fish helps the farmers in meeting their fundamental requirements (John, 2014).

Reports revealed that the homestead farming system in Kerala is facing some challenges in the recent period. These challenges were changes in land use systems, accessibility of agricultural labour, and decline in commodity prices (John, 2014). However, this study suggested that future strategies to advance or impress the existing homestead farming by focusing on water based development with more emphasize on a whole-farm approach, and promoting sustainable models via farmer-participatory approach for each agro-ecological zone.

Attempts were made by Andrews and Kannan (2016) to analyse the land use under homestead from the point of view of land-use change which has been extensively taking place in Kerala. The study was conducted in the Manimooly village of Vazhikkadavu Panchayat in northern part of Malappuram district. The results of study revealed underutilization of land under homesteads owing to lack of suitable incentives for growing in homestead, and suggested that a preference for perennial crops which makes the homestead more homogeneous across households.

The above study further revealed that agriculture was not the main occupation of majority of homestead owners and notable decline was observed in the area under individual homesteads. Still, the prime function of homestead as felt important by the respondents was livelihood support, in addition to other functions like supplementing food, recreation, ornamental gardening and family cohesion maintenance. The study revealed the potential of homesteads in biodiversity conservation. Meanwhile, it directed towards the critical need for promoting development and growth interventions for them, without which the stability of our agro ecosystem may be lost beyond repair.

2.2 IMPORTANCE OF LINEAR PROGRAMMING TECHNIQUE

Dantzig is commonly credited with being the "father" of linear programming techniques. The scientist was involved in military strategic challenges in the US Air force during second world war and the areas of emphasize at the initial stage were on transportation, assignment and deployment decisions and developed and formulated the Simplex method to obtain basic solution of the Linear Programming (LP) model in 1947. The use of linear programming technique was extended to business organizations after the Second World War and has since found applications in various fields of human endeavor.

Linear programming is defined as the most frequently used mathematical programming technique for optimization where, it shows quite exactly what the farmers do or how their behavior changes if the production conditions change (Hazell and Norton, 1986). It is a modern technique used to resolve planning problems logically and mathematically using the Simplex algorithm. For applying this technique, the problem must be defined in terms of an objective function to be maximized or minimized which may undertake a set of constraints that have to be satisfied involving resources available to resources required (Dent *et al*., 1986).

Hardaker *et al.* (1997) stated LP approach, as the most frequent and familiar method of optimizing whole-farm strategies from which to scrutinize the benefits of a novel technology within the whole farm context.

Besides, the optimal solution, LP approach provides sensitivity analysis where the latter evaluates how variations in the objective function coefficients influence the optimal solution of a linear programming model. It could also understand how much variations in objective function coefficients and in the right hand side value affect the optimal solution (Anderson *et al*., 2000).

A linear programming model was used to resolve the optimum cropping pattern as a prerequisite to capable of available resources of land, water, and capital, for Pakistan's agriculture by Hassan (2005). Increasing production per unit area was found to be the only way to meet increasing demand for food, fibre and fuel for the ever increasing population. (Hassan *et al*., 2015).

2.3 APPLICATION OF LINEAR PROGRAMMING IN AGRICULTURE AND FARMING SYSTEM MODELING.

Nagaraja (1995) studied the potential for enhancing farm employment through a capable farming system. The study was conducted in Bangalore district of Karnataka. According to the study, the one with the minimum income variability proportionate with high income was an efficient system. Linear programming and its complements MOTAD (Multiple objective and compromise programming techniques) were used for data analysis. A well-organized farm plan has the potential to enhance farm income by 124 per cent for crop + poultry system of marginal farms, 53 per cent for crop + sericulture system of small farms and 85 per cent for crop +

dairy + sericulture system of medium farms. The efficient farm plan provided the maximum employment for crop + sericulture system in all the categories of farms.

Studies conducted by Shende (2000) to build up optimum cropping pattern in Vidarbha district of Maharashtra by means of LP approach indicated that, cotton (40%) followed by pulses (30%) and hybrid sorghum (25%) crops was found to be the prominent cropping pattern in this district. Cotton followed by hybrid sorghum, pulses and soybean was the observed cropping pattern based on farmer preference in central Vidarbha region. However, mono-cropping with paddy was found most popular in eastern Vidarbha region. Optimum plan developed with the available resources showed scope for increasing the income of the farmers by certain adjustment in existing crop plan with additional capital available to them. As far as maximization of profit at farm level is concerned, cotton, pulses and sorghum were the most suggested crops for western Vidarbha region whereas, cotton, soybean and pulses were recommended for central Vidarbha zone.

Tilekar and Nimbalkar (2000) conducted a study to assess the existing cropping pattern, develop the best crop plans through the technique of linear programming and to analyse the potentials for expanding the net returns. Data was collected in 1995-96, from 106 farms from a village under the Mule Irrigated Command Area in Maharashtra. Stability and strength of optimum crop plans for the variations in output prices and accessibility of resources were also studied. The optimum plans revealed a potential of expanding net farm income to the extent of 37.33, 10.68, 15.30 and 18.08 per cent on marginal, small, medium and large farms respectively.

Kaur (2001) developed optimum combinations of high value enterprises with existing crops for different farm size categories using linear programming in Punjab. It was found that an increase in income of the farmers on the basis of optimum plan developed for various categories varied from 4-68 per cent as compared to the existing plans.

Singh (2001) carried out a study in six tribal villages of Jharkhand, India, during the period of 1996-98 and 378 tribal farmers belonging to different groups were surveyed. Results showed that irrespective of farm categories, pig rearing was found to be a subsidiary occupation of tribal farmers, which was a prime source of income and employment of landless households and contributed 49 per cent to the total annual income of these groups of farmers. In addition, marginal, small and medium categories of farmers in tribal areas of Jharkhand were also found to get substantial annual employment from pig rearing.

A linear-programming farm household model consisting of crop or livestock production which could be made use in different economic and ecological situations in developing countries was designed by Bernet *et al.* (2001). The model was designed with the objective of obtaining awareness about small farmer production systems in three ecological zones in Peru, so as to identify suitable strategies for maximizing expected profitability. The principal production constraints defined in this model include access to availability of land, water, labor, capital and feed. A feed balance for cattle and sheep to assure minimum nutrient intake was also involved in the model. Food or fodder crops were defined for crop production where, the production requisites were water, labor, animal traction, tractor hours and capital. However, there was no mention about soil and weather data with expected yields.

Goswami (2002) designed optimum farm plans for a progressive farming scheme, involving valley land cultivation, terrace cultivation, vegetables and fruits, plantation crops, forestry, fodder and livestock in Meghalaya state of India, at the existing and enhanced level of resources. Study was conducted during 1994-95 where, 40 farmers practicing the above said farming schemes for the past 10 years were interviewed. The findings pointed out that, systematic farm planning was a better suggestion for making enhancements under the existing technology and resource base on the hill farms. The possibilities of further expanding farm income by providing additional human labour and capital were also analysed.

A study was conducted by Singh (2002) to verify the economic benefits of farmers received from livestock, crop and farm forestry enterprises. Survey was carried out in 1996-97 and 1997-98, among 400 tribal farmers of different categories in Ranchi district of Jharkhand. It was found that crop, livestock and farm forestry enterprises were primary sources of farm income of the farmers. Livestock was found to be the major source of farm income of marginal, small, medium and large farmers and as a whole, 60 per cent of total employment generated per annum was from the livestock sector and the remaining 40 per cent was from crop husbandry sector.

Linear programming method was used to attain optimum crop production plans at the farm level (Pawar *et al.* 2002). The study was conducted under both rainfed and irrigated situations where primary data was collected from 90 cultivators. Kharif unirrigated and irrigated land, rabi unirrigated and irrigated land, perennial irrigated land, human and bullock labour, working capital, food grain and fodder requirement were the resource constraints used in the model. As per the study, the difference in input energy use between existing and optimal plans pointed that energy saving was 309.37 MJ/farms, in the irrigated system. The difference between existing and optimum plans showed that the farm income from the optimal plan increased by ₹ 3772.24/- in the rainfed region and by ₹ 4598.04/- in the irrigated region at an overall level.

Role of non-farm income in supporting the economic development in the union territory of Pondicherry was studied by Nasurudeen *et al.* (2003). Linear programming system has been used to optimize sectoral income. Results proved the possibility of increasing income by 4.98 per cent in this area by optimization of the agricultural division and hence recommended to encourage the production of commercial crops which possess greater potential. The territory has potential for enhancing agriculture and agro based industries where the non-farm sector contributed the maximum share of 19.79 per cent proving that potential expansion of utilization of this sector would be a suitable solution for income generation, poverty reduction and increasing the standard of living of the inhabitants. Infrastructural facility development along with employment opportunities and income generation activities would enhance the economic advancement of the union territory of Pondicherry according to the study.

A study was carried out to develop an optimum cropping pattern for sericulture-dominant farms in southern dry zone of the state of Karnataka by Srinivasa *et al.* (2005). The survey was conducted in Kolar and Mysore districts, as they stand for unique techniques of practicing sericulture in Karnataka and 120 farmers were chosen at random for the study. Linear programming was used for acquiring the optimal combination for different enterprises owned by the sample farmers. LP method was made use to work out the maximum achievable returns by small, medium and large farmers via the optimal distribution of different crops, sericulture and livestock, employing the available resources. The results of the study revealed that farmers had to adopt various farm enterprises to attain maximum farm income using family owned resources. The net returns obtained from the recommended farming system turned out to be ₹ 48,831/- per farm as against ₹ 22,175/- under the existing plan. It has been recommended to include crops such as mulberry in the cropping system with bi-voltine silkworm rearing along with dairying for increasing the income. Efforts may be made in the development process to inspire farmers to take up silkworm rearing, as sericulture found to be accessible with the small and marginal farmers.

Kumar *et al.* (2006) conducted a study on expanding income and employment via sustainable farming systems in water scarce area of U.P. Two types of farming systems i) wheat-mustard based and ii) potato-based systems were identified and data was collected from 113 households on the basis of size of each farming system group. The chosen farmers were stratified into different farm size categories and linear programming model was employed to build up to get the optimal farming systems. The LP models were extended to include the integer value of livestock enterprises whereas, remaining activities were used as non-integer in the optimal solutions. Sensitivity analysis was also done to verify the consequence of alterations in the total water availability by four irrigation methods in the optimum farming systems.

Mahendran *et al.* (2006) worked on developing optimum cropping patterns in ground water over exploited area of Perambalur district of Tamil Nadu. In order to maximize combined net income from farm crops, LP technique was adopted by collecting data from 120 farmers under various irrigation sources *viz*, open wells, tub wells and open cum tube wells in vital and over exploited ground water system and in semi-critical and safe ground water regime.

According to the study conducted by Nedunchezhian and Thirunavukkarasu (2007) on optimizing farm plans in various farming systems revealed that dairy and sheep rearing could be more striking for marginal farmers as far as income and employment generation are concerned. As per the study, 15 goats and 15 sheeps could be efficient for expanding their income and employment. Income increase in response to optimal plans was found to be maximum (223.50 per cent) in large farmer group, followed by small (192.70 per cent), marginal (180.10 per cent) and landless households (116.00 per cent).

Subhadra (2009) conducted a study to identify the optimum activity mix of dairy enterprise and crop production to enhance farm income with the given resource use efficiency and technology in Thrissur and Palakkad districts of Kerala. It was found that net income of different farm size groups could be enhanced in between ₹ 4,275/- to ₹ 15,252/- by adding two animals to large and small farmers each and three animals to marginal farmers.

Muncan (2010) carried out a study with the main objective of identifying the perfect structure of production and to facilitate the realization of maximum profit by employing the obtainable production resources (land, mechanization, labor forces). Simplex method of linear programming was used as the basic system of planning. The primary model for optimization of the field crop production has started with the existing pattern involving wheat, maize, sunflower and soybeans, and the optimization of function to maximizing the gross margin was accomplished by adopting linear programming. Second model was designed so as to maximize the use of accessible resources where the model included sugar beet as a fifth crop. The models of optimal production structure showed that employing modern methods in production plan was one among the cheapest and safest methods for expansion of agricultural enterprises.

Dey and Mukhopadhyay (2010) adopted the technique of linear programming to inspect the outcome of optimal distribution of resources on net farm returns. Net returns obtained from optimal crop plan I which was obtained following resource restriction on land, working capital and family labour along with provision of hiring of human labour exceeded the net return earned from existing distribution of resources (existing crop plan) by 43 per cent. Optimal crop plan II which was developed by some reduction in working capital reported about 13 per cent increase in net return as compared to optimal crop plan I.

Kamble *et al.* (2010) conducted a study to recommend optimal resource allotment of land and water by employing linear programming for Amaravati district in Maharashtra. The net income increased from ₹ 4,906/- per hectare in the existing plan to ₹ 9,642/- per hectare in newly developed plan and thus recording an increase of 96.53 per cent.

A study was carried out on the optimum distribution of resources in vegetable farming in Parganas district of West Bengal. In optimal crop plan, resources were distributed in favour of brinjal and pointed gourd. An increase of 49.79 per cent in the net returns from optimal crop plan, over the net returns in the existing crop plan was recorded (Dey, 2011)

Rajeswari *et al*. (2011) worked the prevailing cropping model of farmers in Kadapa district of Andhra Pradesh and reported that sub-optimal distribution of resources in the existing plan. An optimum crop enterprise model was developed by them which showed a considerable scope of expansion in the income by 73.67 per cent among the small and 44.87 per cent among large farmer respectively, over the existing plan. The existing crop production model on kharif irrigated area consisted of paddy, bajra, groundnut, sunflower and brinjal. Increase in area under brinjal and sunflower, decrease in area under paddy cultivation and elimination of bajra and groundnut was recommended as per the optimal model. In rabi, the optimum plan has recommended to increase the area under cultivation of vegetables such as tomato, onion and chilli by entirely eliminating the prevailing crops like paddy, ginger and okra.

Mohamad and Said (2011) developed linear programming crop mix model with the purpose of maximizing the total returns for a finite-time planning horizon subjected to restricted accessible resources such as budget and land acreage and then transformed into a multi-period linear programming problem. This optimal cropping system involved the collective cultivation of spinach, pak choy and lettuce. The findings assured higher returns even for a comparatively short planning horizon of 12 months.

Majekel *et al*. (2013) developed a linear programming model to determine the optimal crop combination for a rural farmer in Zimbabwe. Crops considered were maize, soyabeans and cotton. The model produced an optimal crop combination which gave a higher income compared to the farmer's plan. The income difference was 73 per cent.

Vani (2013) examined the potential and prospects of rising net farm returns and employment of the farmers in Kadapa district of Andhra Pradesh by balanced distribution of obtainable resources by means of linear programming technique. The study revealed the scope of reorganizing the resources in order to amplify the net farm income to the extent of 63.48 and 70.51 per cent over the prevailing plan among the small and large farmer respectively. In accordance with the optimum model, a complete fallow of kharif dry land was recommended along with reducing the area under rice production from 0.47 ha to 0.42 ha on kharif irrigated land and elimination of existing crops like groundnut, turmeric and onion. Distribution of whole dry land for the production of bengal gram was recommended in rabi. Besides, the optimum model has also recommended enhancing area under black gram, chilli, tomato and brinjal over the existing plan and to condense the area under rice and elimination of groundnut and sesame in cropping system of rabi irrigated land.

Igwe *et al*. (2013) applied linear programming technique to solve a maximization problem of gross margin among a combination of existing enterprises in Ohafia zone of Abia State, and formulated a plan where the difference in optimum gross margin for Ohafia was 73 per cent.

Conclusions and implications from the review:

The literature reviewed above has highlighted the significance of farm planning at micro level. Studies revealed the fact that farm income could be enhanced in considerable amount by means of appropriate farm planning by selecting suitable enterprises-mix and judicious use of scarce resources.

It was also observed that linear programming was the most frequently used technique to develop optimum farm plans under diverse situations. It is also obvious from the above cited literatures; optimum models developed by means of linear programming may be quite fruitful to expand the income of the farmers. This signifies the urge to promote and undertake such studies.

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

The present study was under taken in Southern laterites (AEU 8), South central laterites (AEU 9) of Thiruvananthapuram district of Kerala with the specific objective to develop statistical models for the homestead farming systems that maximizes farm income by the optimal use of available resources. This chapter presents the procedural details in selecting the sample, methods of analysis in the following headings.

3.1 Description of study area

3.2 Sampling design

3.3 Materials: Collection of primary data

3.4 Principle features of the sample

3.5 Methods: Statistical tools and techniques employed

3.6 Basic assumption

3.7 Simplex algorithm and sensitivity analysis

3.1 DESCRIPTION OF STUDY AREA

Thiruvananthapuram district is classified into five Agro ecological units (AEU's) *viz.,* AEU 1, AEU 8, AEU 9, AEU 12, AEU 14 (Fig. 1) based on their location and climate. Table 1 gives the area of each agro ecological unit with percentage share of each AEU. Agro ecological unit 14 *i.e.*, Southern High Hills has 26.48 per cent of the geographical area of Thiruvananthapuram district while AEU 1: Southern Coastal Plain occupies only 9.34 per cent (Fig. 2). 25.94 per cent of the total area is in AEU 9 *i.e.*, Southern Central Laterites, 24.82 per cent of the total area is in AEU 8 Southern Laterites and 13.42 per cent in AEU 12 *i.e.*, Southern Foot Hills.

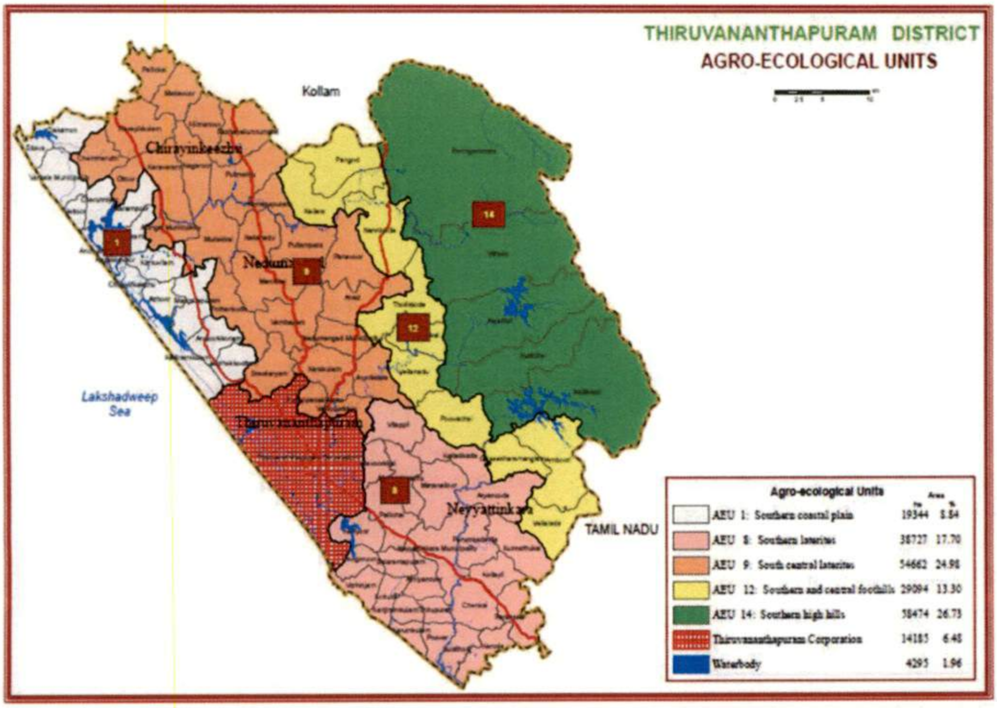


Fig. 1. Agro-ecological units of Thiruvanathapuram District

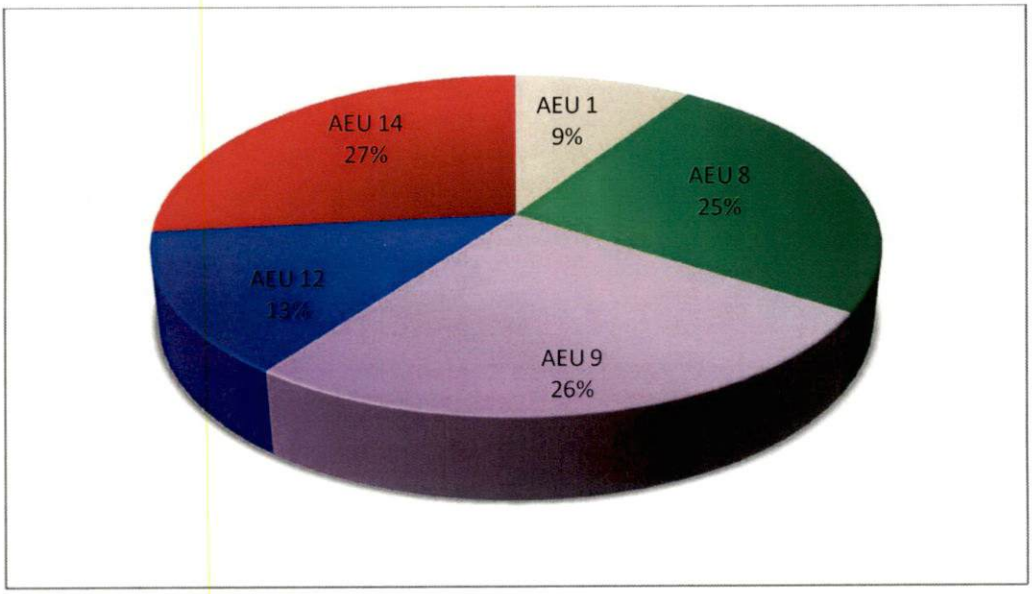


Fig.2. Area of Agro Ecological Units as percentage to the total in Thiruvananthapuram district

Table 1. Classification of Thiruvananthapuram district into Agro Ecological Units

Sl.No.	Agro-ecological Unit	Area(sq.km)	percentage
1	Agro-ecological Unit1: Southern Coastal Plain	204.77	9.34
2	Agro-ecological Unit8:Southern Laterites	544.00	24.82
3	Agro-ecological Unit9:Southern Central Laterites	568.59	25.94
4	Agro-ecological Unit12:Southern Foot Hills	294.21	13.42
5	Agro-ecological Unit14:Southern High Hills	580.43	26.48
	Total	2192.00	100.00

3.1.1 Southern Laterites (AEU 8)

The Southern laterites agro-ecological unit spread over 24 panchayaths in south-western part of Thiruvananthapuram district is delineated to represent the uniqueness of climatic and soils. The area has tropical moist sub humid monsoon climate receives low rainfall compared to the other areas of midland laterites (mean annual temperature 27.1 ^{o}C; rainfall 1884 mm). Soils are acid and having low activity lateritic clay. This unit covers 38,727 ha area.

AEU 8 covers all the panchayaths of Athiyannur, Nemom, and Parassala block, four panchayaths from Perumkadavila block and one panchayath from Vellanadu block. This unit also includes Neyyatinkara municipality and Thiruvananthapuram Municipal Corporation.

Table 2. Constitution of southern laterites (AEU 8)

AEU Name	**Constitution**		
Southern laterites (AEU 8)	Athiyannur	Kanjiramkulam	Kattakkada
	Karumkulam	Kottukal	Venganoor
	Vizhinjam	Balaramapuram	Kalliyoor
	Malayinkeezhu	Maranalloor	Pallichal
	Vilappil	Nemom	Vilavoorkkal
	Chenkal	**Karode**	**Kulathoor**
	Parassala	Poovar	Thirupuram
	Aryancode	Kunnathukal	Kollayil
	Perumkadavila	Neyyattinkara (M)	

Coconut based cropping system is prevailing in the unit which accounted for nearly 32 per cent of the cultivable area and majority of the panchayaths comes under this system. Rubber based cropping system is practiced over 20 per cent of the cultivable area followed by arecanut based cropping system (over 15 per cent of the cultivable area). Other major cropping systems practiced in the unit are rice based and banana based system.

Among coconut based cropping system, coconut intercropped with banana, coconut + pepper +banana, coconut + pepper + banana + tapioca and coconut + other crops (homesteads) are the major cropping systems practiced in majority of panchayaths.

Karode panchayath covers an area of 1567 ha. This panchayath has a population of 31649 with 15707 males and 15942 females. The density of population is 2020 persons per sq.km and the sex ratio is 1015 females/1000 males. The literacy rate reported here is 85.73 per cent. The main crop cultivated in this panchayath is coconut.

Kulathoor panchayath has an area of 1124 ha. The major crop cultivated in this panchayath is coconut. As per census (2011), this panchayath has a population of 33140 with 16563 males and 16577 females. The density of population is 2948 persons per sq.km and the sex ratio is 1001 females/1000 males. The literacy rate of this panchayath was 80.92 per cent. The land utilization pattern of both villages is shown in Fig 3.

The total cultivatable area was more in Kulathoor (2865 ha) compared to Karode (1474 ha) but the net cropped area was more in Karode (1469 ha) as compared to Kulathoor (953 ha).

3.1.2 South Central Laterites (AEU 9)

The South central laterites agro-ecological unit is delineated to represent midland laterite terrain with typical laterite soils and short dry period. The unit covering 161 panchayats of midlands extended from Thiruvananthapuram to Ernakulum district. The climate is tropical humid monsoon type (mean annual temperature

26.5 °C; rainfall 2827 mm), Soil of the southern half of Thiruvananthapuram are deep, strongly acid, red loamy where as in the other parts it is deep, strongly acid, red, very gravelly clay. It covers 3,65,932 ha area.

AEU 9 consisted of Mudakkal grama panchayath of Chirayinkeezhu block, Pothenkode and Sreekariyam grama panchayaths from Kazhakkuttom block, whole area of Kilimanoor, Nedumangad and Thiruvananthapuram rural block, four grama panchayaths of Vamanapuram and two grama panchayaths of Varkkala blocks (altogether 24 gramapanchayaths) and 2 municipalities *viz.*, Attingal and Nedumangad municipalities. AEU 9 includes ten panchayaths from three blocks (Perumkadavila, Vamanapuram and Vellanadu blocks).

Table 3. Constitution of south central laterites (AEU 9)

AEU Name	**Constitution**		
South central laterites (AEU 9)	Mudakkal	Pothencode	Sreekaryam
	Karavaram	Kilimanoor	Madavoor
	Nagaroor	Navaikulam	Pallickal
	Pazhayakunnummel	Pulimath	**Anad**
	Aruvikkara	Karakulam	Panavoor
	Vembayam	Kudappanakunnu	Vattiyoorkavu
	Manikkal	Nellanad	Pullampara
	Vamanapuram	Chemmaruthy	Ottoor
	Attingal (M)	Nedumangad (M)	

Major cropping system practiced in the unit is coconut based and rubber based followed by arecanut and banana based cropping system. Among coconut based systems, mono cropping of coconut constitute major share in the cultivable area. Coconut intercropped with pepper and banana is another major coconut based system. Among the various intercrops in coconut based homesteads, banana occupies maximum. Elephant foot yam, colocasia and tapioca occupies major proportion among other intercrops grown in the unit.

Vembayam grama panchayath has an area of 30.59 ha. This Panchayath has a population of 35388 with 17121 males and 18267 females. The density of population is 1157 persons per sq.km and the sex ratio is 1067 females/1000 males. The literacy rate reported was 87.15 per cent.

Anad gramapanchayath has an area of 2415 ha which came into existence on 1952. This panchayath has a population of 30491 out of which 14782 are males and 15709 are females. The density of population is 1263 persons per sq.km and the sex ratio is 1063 females/1000 males. The literacy rate of this panchayath is 88.92 per cent. The major crops of this panchayath are coconut and rubber.

Fig. 4 represents the land utilization pattern of both villages. Total cultivable area available in both panchayaths was more or less equal (2176 and 2093 ha for Anad and Vembayam respectively).

3.2 SAMPLING DESIGN

Three stage sampling technique was used for drawing samples for the present study. At first stage, Thiruvananthapuram district, one of the agriculturally advanced districts of Kerala state was purposively selected because of the features like 50 per cent total population depends on agriculture for their livelihood, Most of the people are engaged in low remunerative pursuits which require very little capital, it is the densest district in Kerala with 1,509 residents per square kilometer and homestead farming, being the more common pattern of the district.

At the second stage, from the district AEU 8 and AEU 9 are purposively selected which constitute almost 42.68 per cent total area of the district. The list of panchayaths under the selected agro-ecological units (AEU 8 and AEU 9) of Thiruvananthapuram district is prepared and after discussion with technical experts in the department of agriculture two panchayaths with maximum number of homesteads purposively identified from each selected agro-ecological unit. The selected panchayaths were Kulathoor and Karode from AEU 8 and Anad and Vembayam from AEU 9.

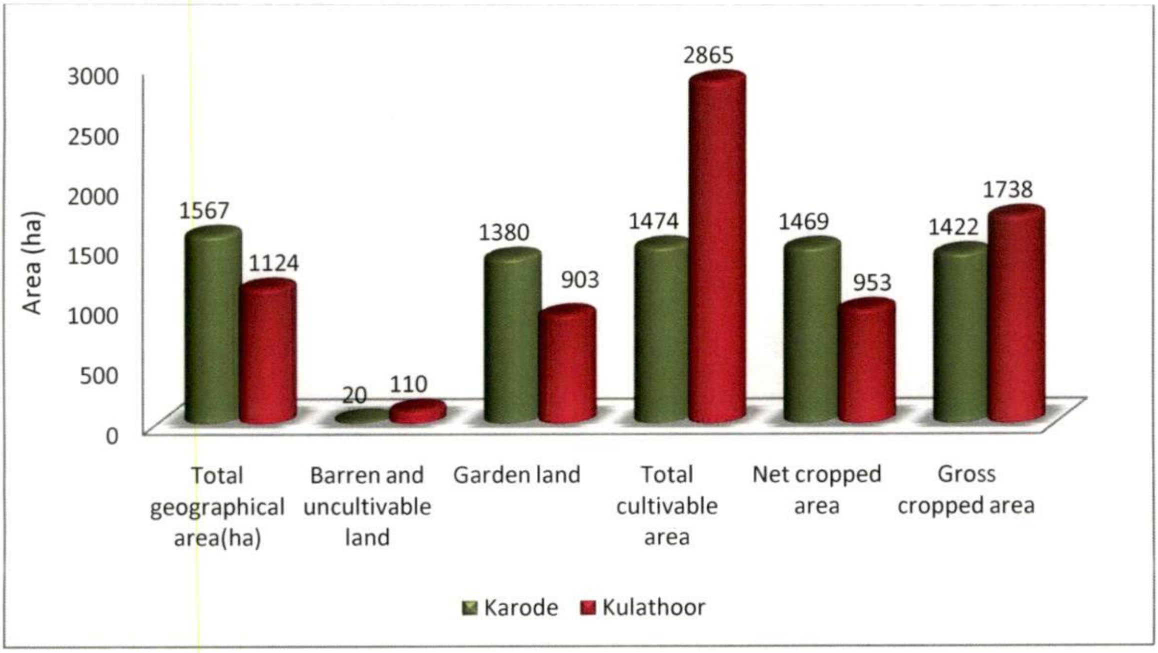


Fig.3. Comparison of Land Utilization Pattern between Karode & Kulathoor panchayaths in Thiruvananthapuram

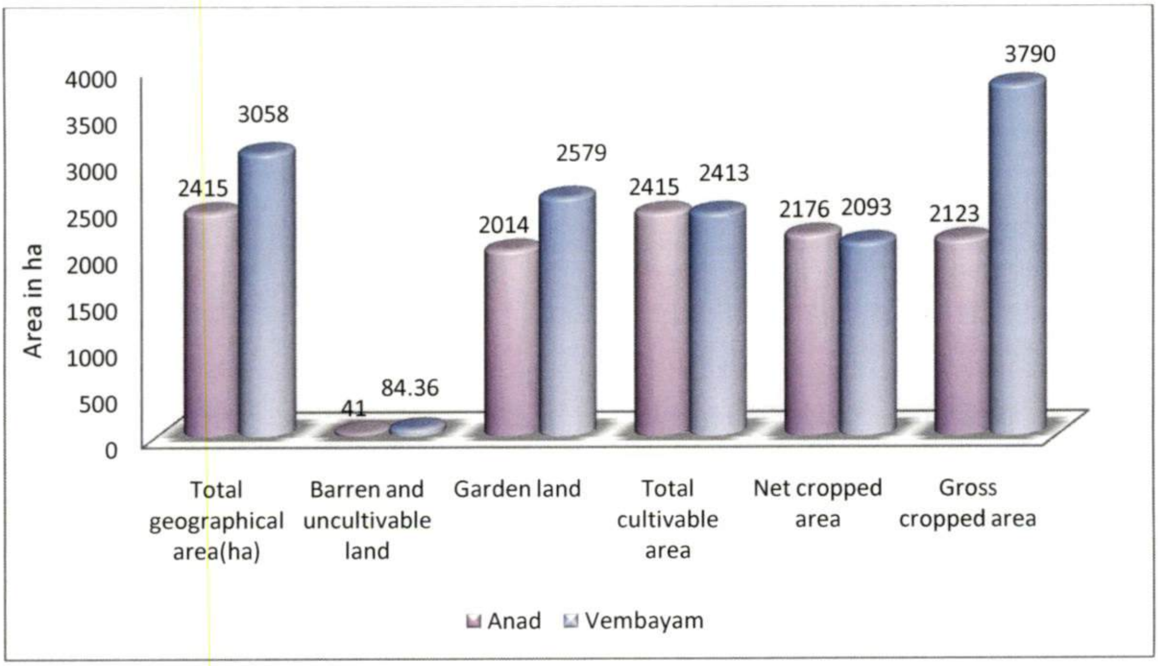


Fig.4. Comparison of Land Utilization Pattern between Anad & Vembayam panchayaths in Thiruvananthapuram

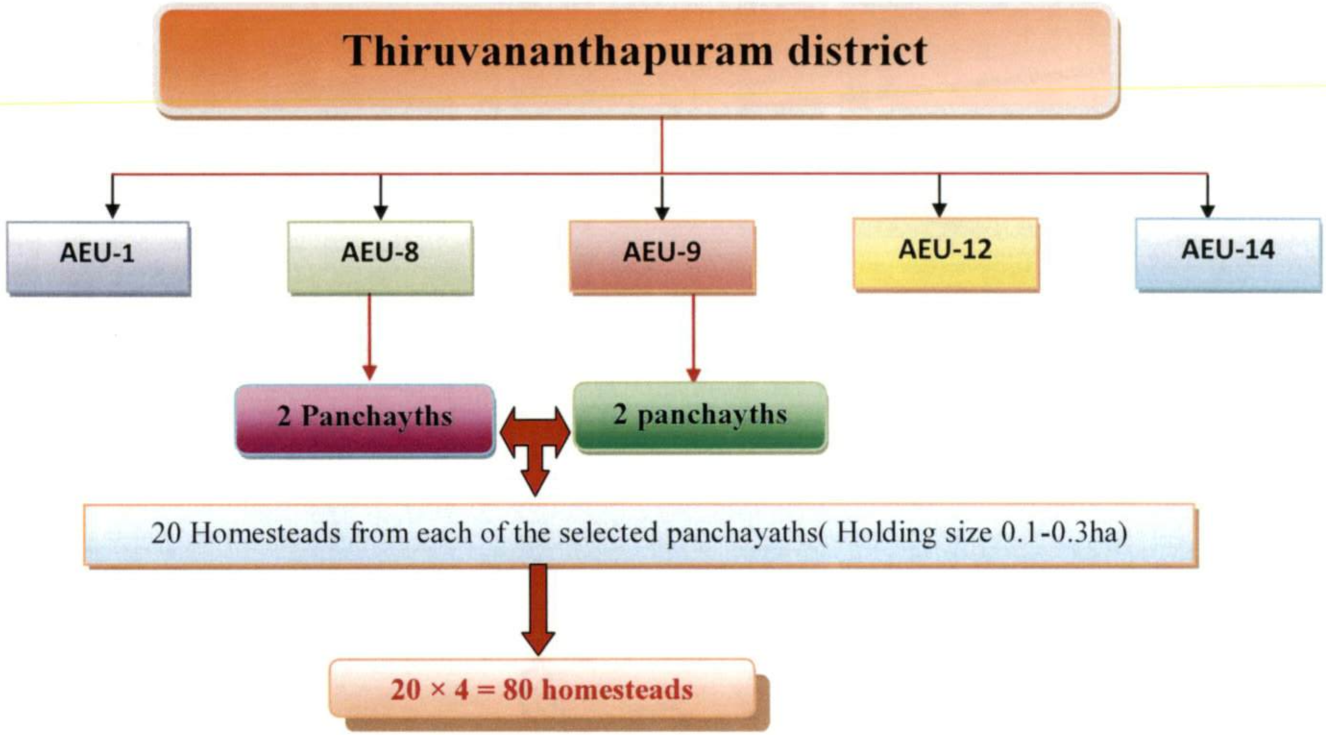


Fig.5. Sampling frame of the study

Finally at the third stage 20 homesteads having similar type of cropping/farming systems and holding size between 0.1-0.3 ha was selected at random from each of the selected panchayaths. Therefore, the total sample size for the present study was eighty. The sampling frame for the study is shown as Fig 5.

3.3 COLLECTION OF DATA

Data for the study was collected from the respondents by the personal interview method using pre-tested structured schedule covering all aspects relating to the inputs and outputs of various enterprises in the homesteads. The information collected includes socio-economic profile comprised of age, education, family size, occupational status and annual income were collected from selected respondents, details on existing farming systems, crops, area under each crop, income from each crop, quantity and cost of various inputs, quantity and price of output, hired and family labour, irrigation status, details on livestock and poultry. The reference period for the study was the agriculture year 2016-2017.

3.4 PRINCIPLE FEATURES OF THE SAMPLE

The selected homesteads followed coconut based cropping system which grouped separately for both AEU's into three on the basis of existing cropping/farming system in the homesteads (HFS), *viz.,* system-I (S1) consisting of crops alone, system-II (S2) including crops, poultry and goat and system-III (S3) comprising of crops, poultry and all livestock. Such a classification was made as the state planning board to prepare strategies and action plan for each AEU for the development of agriculture and allied sectors and within AEU classification was resorted to as the nature of farming decision of these groups differed considerably from one another. Rest of the analysis was done for each of these categories separately.

The homestead crops, particularly the perennials exist as a mixture without specific demarcation of area for individual crops. The number of plants of each crop in each holding was recorded along with basal area occupied by them however, only adult bearing perennials were considered in the study.

3.5 METHODS: STATISTICAL TOOLS AND TECHNIQUES EMPLOYED.

Tabular analysis involving the computation of averages, percentage share and meaningful discussions based on literature review etc. was employed to present the data regarding the socio-economic profile of selected respondents, characteristics of average farms including existing cropping pattern and resource use pattern.

The benefit-cost analysis worked out for average farm size by considering, different costs and returns incurred in cultivation of crop as well as rearing livestock and poultry. Cost of cultivation is taken into account in the case of annuals and biennials, whereas only maintenance cost is considered for perennials, livestock and poultry.

3.5.1 Statistical Optimization Models Employed

Optimum allocation of resources is defined as one, with given physical, technical and resource conditions, that shows activities to undertake and how much of each resources to allocate to each activity so that the net farm returns are maximized in a year. Among the various optimization models available for allocation of scarce resources among alternative enterprises, linear programming (LP) is the most power and efficient tool applied to farm activities to determine mathematically the optimum plan for the choice and combination of farm enterprises, so as to maximize the income within the limits of available farm resources. Linear programming is the most widely and best understood optimization method which can effectively handle a number of linear constraints and variables (activities) simultaneously. Hence, the Simplex method of LP was employed to develop optimized homestead models. The Simplex method involves formulation and maximization of a linear objective function subject to a set of inequalities.

3.5.1.1 Mathematical Formulation of the Model

In linear programming, a linear function of number of variables is to be maximized subjected to number of linear constraints. The linear programming model used was of the following form:

Maximize $z = \sum_{j=1}^{n} c_j x_j$

$j = 1$ to n activities

Subject to following constraints

$$\sum_{j=1}^{n} a_{ij} x_j \leq or = or \geq b_i$$

$x_j, b_j \geq 0$ (Non negativity constraint)

Where, $z =$ Objective function is to be maximized

$c_j =$ Unit net return from jth activity/ enterprise

$x_j =$ Real number of jth production activity/ enterprise to be determined

a_{ij}, $b_i =$ Fixed real constants

3.5.1.2 Objective Function

The role of objective function in this study was to maximize the net income from the homesteads subject to the specified constraints in the model. The net return was measured by deducting operative expenses from gross return. The various items of operative expenses were input cost (cost of seeds, manures, fertilizers and plant protection chemicals), labour cost (both family and hired labour) and miscellaneous expenses. The cost associated to family and hired labour was calculated using paid out wages prevailing in the villages during the period of study. In this LP model, the objective function developed was to be optimized to get maximum return from homestead and the objective coefficient used was net return from each enterprise per year.

3.5.1.3 The Constraints

A set of constraints are those which allow the unknowns to take on certain values but exclude others. They are conditions that must be satisfied to render the design to be feasible. The constraints included in the analysis were total area, intercropped area, investment amount and population of each enterprise.

3.6 BASIC ASSUMPTION

Beside the general assumptions of linearity, additivity, certainty, non-negativity and divisibility, the following particular assumptions were made in developing the model.

3.6.1 Total Area

The models is developed for an average homestead size of 0.18 ha for AEU 8 and 0.21 ha for AEU 9 respectively, which includes area of house and permanent structures, net cropped area and uncultivated land.

3.6.2 Intercropped Area

The interspace accessible was assessed after excluding the area occupied by the house and permanent structures and the area occupied by the basins of coconut and other tree components.

3.6.3 Investment Amount

All the activities are financed internally and the farmer is not dependent upon external financing in the form of credit. The third quartile value of the investment was considered while developing the model rather going for higher value of the investment by the homestead farmers of each system.

3.6.4 Population of each Enterprise

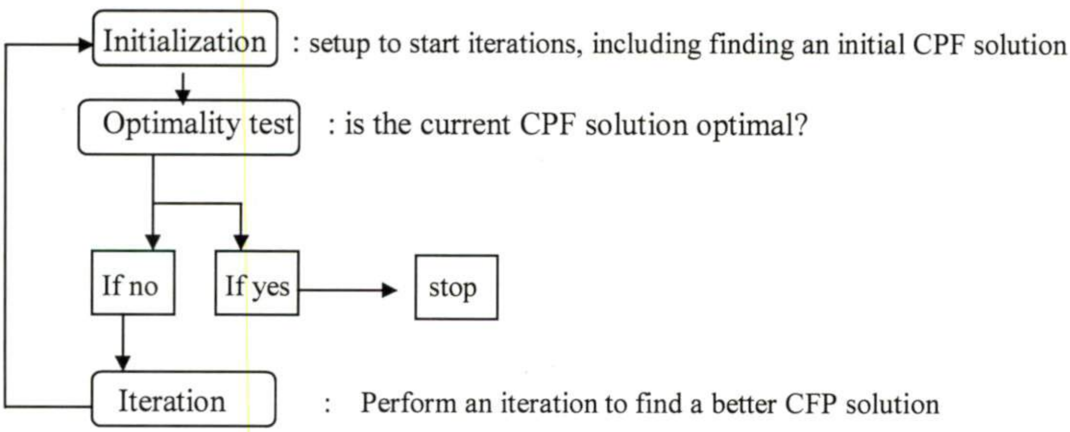
The constraints with respect to the population of different enterprises included in the model were decided so as to meet the multiple demand of the farm family by enterprise diversification, optimize the available resources and maximize the gross returns. Modal value, the tastes and preferences of the farmer and his constraints in increasing or decreasing the population of each enterprise was considered for developing constraints on population of each enterprise. Coconut is the base crop in the model, as all homesteads are coconut-based in southern Kerala, adequate number of coconut palms has maintained in the model. A vegetable garden unit has of 40 m^2 area and the optimum model was developed by giving more emphasis to safe to eat vegetable cultivation by at least doubling the area under vegetable cultivation over the existing plan.

The above assumptions govern the constraints against which the model is developed.

3.7 SIMPLEX ALGORITHM FOR LINEAR PROGRAMMING

3.7.1 Simplex Method

Simple method is an iterative procedure or algorithm to find the optimal solution of an LPP involving more than two variables. This method consists of developing a series of solutions in tabular form, referred as tableaus. By looking the bottom row of each tableau, one can directly tell, it represents the optimal solution or not. The first tableau corresponds to the origin. Succeeding tableaus are advanced by shifting to a bordering corner point in the way that gives the maximum profit. Every tableau approaches to a corner point feasible solution (CPF). This procedure continues as long as a positive rate of profit exists. The flow chart of simplex algorithm is given as follows.



3.7.1.1 Simplex Method for Maximization Problem

The Simplex method for a maximization problem is described in this section. Consider the general linear programming problem of

Maximize $Z = c_1x_1 + c_2x_2 +,\ldots+ c_nx_n$

subject to,

$$\begin{aligned} &a_{11}x_1 + a_{12}x_2 \;+,\ldots+ a_{1n}x_n \le b_1 \\ &a_{21}x_1 + a_{22}x_2 \;+,\ldots+ a_{2n}x_n \le b_2 \\ &\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \\ &a_{m1}x_1 + a_{m2}x_2 \;+,\ldots+ a_{mn}x_n \le b_m, \end{aligned}$$

Where, $x_1, x_2, \ldots, x_n \ge 0$; $x_1, x_2, \ldots, x_n$ are used to represent 'n' enterprises in the homesteads. $c_j, j = 1,2,\ldots,n$ are the objective function coefficients of the enterprises and the unit net return of the enterprises are taken as coefficients for developing optimum homestead model,

$b_i, i = 1,2,\ldots m$, are available resources expressed in terms of populations, area, and amount of investment, and $a_{ij}, i = 1,2,\ldots m; j = 1,2,\ldots n$ are the input output coefficients. In matrix form, the LPP can be written as Maximize $z = c^T x$

Subject to $Ax \le b$, $x_i \ge 0$,

With $x^T = (x_1, x_2, \ldots x_n), c = (c_1, c_2, \ldots, c_n)$, A is a $m \times n$ matrix of input-output coefficients and $b^T = (b_1, b_2, \ldots . b_m)$

3.7.1.2 Converting Inequalities to Equalities

The linear constraints written in the form of inequalities are converted into equalities by introducing non-negative variables generally known as slack variables represented as $s_1, s_2, \ldots, s_n$.

They are;

$$a_{11}x_1 + a_{12}x_2 +, \ldots + a_{1n}x_n + s_1 = b_1$$
$$a_{21}x_1 + a_{22}x_2 +, \ldots + a_{2n}x_n + s_2 = b_2$$
$$\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots$$
$$a_{m1}x_1 + a_{m2}x_2 + \ldots + a_{mn}x_n + s_m = b_m$$

$$\text{where}, x_1, x_2, \ldots, x_n \geq 0,\ s_1, s_2, \ldots, s_m \geq 0$$

3.7.1.3 Initial Basic Feasible Solution

An initial basic feasible solution of an LPP is obtained by putting the basic variables $x_1 = x_2 = \ldots = x_n = 0$. Therefore, the initial feasible solution of an LP becomes $s_1 = b_1, s_2 = b_2, \ldots, s_m = b_m$

Table 4. Initial simplex tableau representing initial basic solution

	C_j	C_1	C_2	C_3	...	C_n	0	0	0	...	0	Z=0
C_{Bi}	Basic variables B	X_1	X_2	X_3	....	X_n	S_1	S_2	S_3	....	S_m	Initial solution values $B(=x_B)$
0	S_1	a_{11}	a_{12}	a_{13}	...	a_{1n}	1	0	0	...	0	b_1
0	S_2	a_{21}	a_{22}	a_{23}	...	a_{2n}	0	1	0	...	0	b_2
0	S_3	a_{31}	a_{32}	a_{33}	...	a_{3n}	0	0	1	....	0	b_3
...	....	.....	......	.....	....	....	....	....	...	...	0	.....
O	s_m	a_{m1}	a_{m2}	a_{m3}	...	a_{mn}	0	0	0	....	1	b_m
	z_j-c_j	$-c_1$	$-c_2$	$-c_3$	...	$-c_n$	0	0	0	...	0	

Where, C_j's are coefficients of (m+n) variables in the objective function, C_{Bi} are the coefficients of the current basic variables in the objective functions,

$$Z_j = \sum a_{ij} C_{Bi}, \text{ where } i = 1,2,\ldots,m\text{; for each } j = 1,2,\ldots n + m,$$

B is vector of basic variables in the basis, X_B the solution values of the basic variables and $Z_j - c_j$ are used as criteria to determine the optimum feasible solution.

If all the values of $Z_j - c_j$ are non-negative, the current feasible solution be the optimal solution. If there are one or more negative values, choose the variables which has minimum $Z_j - c_j$ (most negative), that column is considered as the pivot column. Then divide the X_B column (solution column) by the corresponding positive coefficients (a_{ij}) in the pivot (key) column, and compare the ratios. The row that provides the minimum ratio is called the pivot row. `However, division by zero or negative coefficients in the pivot column is not considered. In the case of tie, break it arbitrarily. Then the variable corresponds to pivot column will enter and variable corresponds to pivot row will leaves in the basic variables B. The number that lies at the intersection of the pivot column and pivot row of the given table is referred as pivot element. The value in the replacing row may be obtained by dividing the pivot row elements by the pivot element and the numbers in the remaining rows may be calculated by using the following formula.

$$\text{New number} = \text{old number} - \frac{(\text{corresponding no of key row}) \times (\text{corresponding no of key column})}{\text{pivot element}}$$

3.7.1.4 Checking for Optimal Basic Feasible Solution

Formulate the second tableau and determine $Z_j - c_j$ and if all $Z_j - c_j$, are positive or zero, then optimal solution exits, otherwise continue the above procedure until all $Z_j - c_j$ are either zero or positive.

3.7.2 Sensitivity Analysis

In LP models, objective function coefficients and the constraints are given as input data or as parameters of the model. The optimal solution is achieved by the values of these coefficients and the coefficients are chosen from the sampled data. Hence, the solution of a practical problem is not complete with the mere determination of the optimal solution. The variation in available resources in terms of R.H.S and objective function coefficients changes the LP problem which may in turn influence the previous optimal solution. Sensitivity analysis helps to study how the optimal solution will change with changes in the input coefficients further or sensitivity is a post-optimality analysis of a linear program. Sensitivity analysis allows us to conclude how "sensitive" the optimal solution to changes in data values.

Sensitivity analysis considers two types of changes such as change in

1. Objective function coefficient (OFC) and
2. Right Hand Side (RHS) value of a constraints or available resources.

3.7.2.1 Shadow Price (Dual Price)

Shadow Price is the amount that the objective would get better as the RHS, or constant term, of the constraint is increased by one unit. Shadow price is defined as the change in objective function coefficients corresponding to a unit change in available resources.

3.7.2.2 Range Report

A range report demonstrates range of variation in objective function coefficient as well as range of available resources. Moreover, a change in the objective function coefficient without changing any of the optimal values of the decision variables and change a row's constant term (also referred to as the right-hand side coefficient) without causing any of the optimal values can be determined from the range report. We can change a coefficient by any amount up to the amount that is indicated in the range report without interfering the optimal solution.

Results and Discussions

CHAPTER IV

RESULTS AND DISCUSSIONS

Keeping in view the objectives of study, homestead farmers of AEU 8 and AEU 9 were classified based on the data collected regarding the cropping/farming system (HFS) followed by them, and the data was analyzed by employing suitable statistical techniques. The results obtained in the study and conclusion drawn in the discussion refers to an average holding size of homesteads of both AEU's. Linear programming was employed to develop optimal plans for three different HFS's in two AEU's individually; thus six optimal models are developed in the study. This chapter presents the results in line with the objectives of the study under the following heads.

4.1 Socio economic profile of the respondent farmers.

4.2 Characteristics of existing Homesteads.

4.3 Cropping/farming pattern and economic analysis of average homesteads.

4.4 Cropping/Farming pattern under different optimum homestead models.

4.5 Comparison of optimum homestead models under different cropping and farming systems

4.6 Sensitivity analysis of different optimum models.

4.1 SOCIO ECONOMIC PROFILE OF THE RESPONDENT FARMERS

From the collected primary data, socio economic status of the farmers was analyzed and discussed in detail in the following sub headings. Socio-economic status of the respondents is measured in terms of age, educational status, family size, holding size, primary and secondary occupation and annual income. The per cent distribution of the variables were prepared and presented in Table 4 - 8.

4.1.1 Age

Table 5. Age-wise distribution of the respondent farmers

Sl.No.	Category (Years)	AEU-8 (n=40)	AEU-9 (n=40)	Total (n=80)
1	Young <35 years	9(22.50)	10(25.00)	19(23.75)
2	Middle 35-55 years	20(50.00)	15(37.50)	35(43.75)
3	Old >55 years	11(27.50)	15(37.50)	26(32.50)

Figures in parentheses denote percentage to total

From the table 5, it is clear that 43.7 per cent of the respondents belonged to middle aged group, 32.50 per cent to old aged and 23.75 per cent were found to be youngsters.

It was noted that half of the respondents in AEU 8 belonged to middle aged category whereas 22.5 per cent was occupied by youngsters. However in AEU 9, old and middle age were found to be in equal proportion *ie*; 37.5 per cent each (Fig. 6).

Hence, it is inferred that almost half of the homesteads in these agro ecological units were maintained by farmers having age in between 35 to 55 years category and majority of the homestead respondents belonged to the middle aged and old aged category. This was because the senior most in the home was usually considered to be the head. A similar result was reported by Rahul (2013) and Thasneem (2016).

4.1.2 Education

Table 6. Educational status of the respondent farmers

Sl.No.	Educational status	AEU-8 (n=40)	AEU-9 (n=40)	Total (n=80)
		Frequency	Frequency	Frequency
1	Primary and Upper primary	12(30.00)	2(5.00)	14(17.50)
2	Secondary and Higher secondary	18(45.00)	20(50.00)	38(47.50)
3	Graduation	7(17.50)	13(32.50)	20(25.00)
4	Post-graduation	3(7.50)	5(12.50)	8(10.00)

Figures in parentheses denote percentage to total

The results presented in table 6 shows that 47.5 per cent of respondents had secondary and higher secondary educational status. Only 10 per cent of total respondents were found to have post graduation whereas 25 percent had graduation. It was found that only 17.5 per cent of the total respondents had educational status, primary and upper primary.

It was noted that 30 per cent of respondents in AEU 8 falls under primary and upper primary educational status while in case of AEU 9, only 5 per cent of the respondents were under this category (Fig. 7). The association between age and education of the respondents is tested using χ^2 test and the calculated value (20.55) of test statistics revealed that there was significant association between these two variables.

Hence it is inferred that more than 70 per cent of the homestead farmers had educational status from school to college level. This result is a reflection of the privileged literacy rate of Kerala State. The result was in conformity with the studies conducted by Thomas (2004), Jayawardana (2007) and Reeba (2015

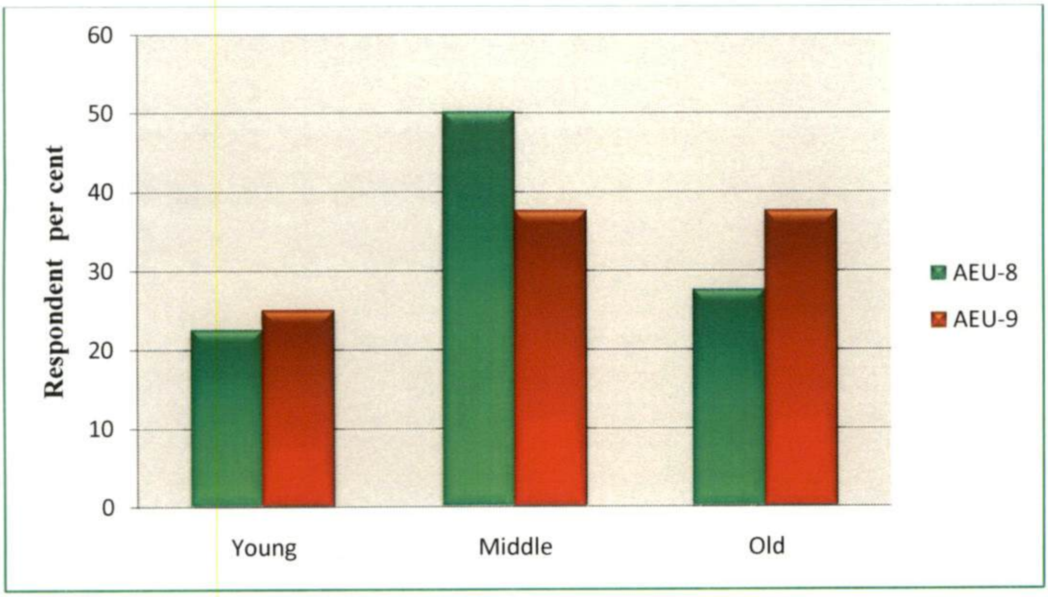


Fig. 6. Distribution of respondents according to age

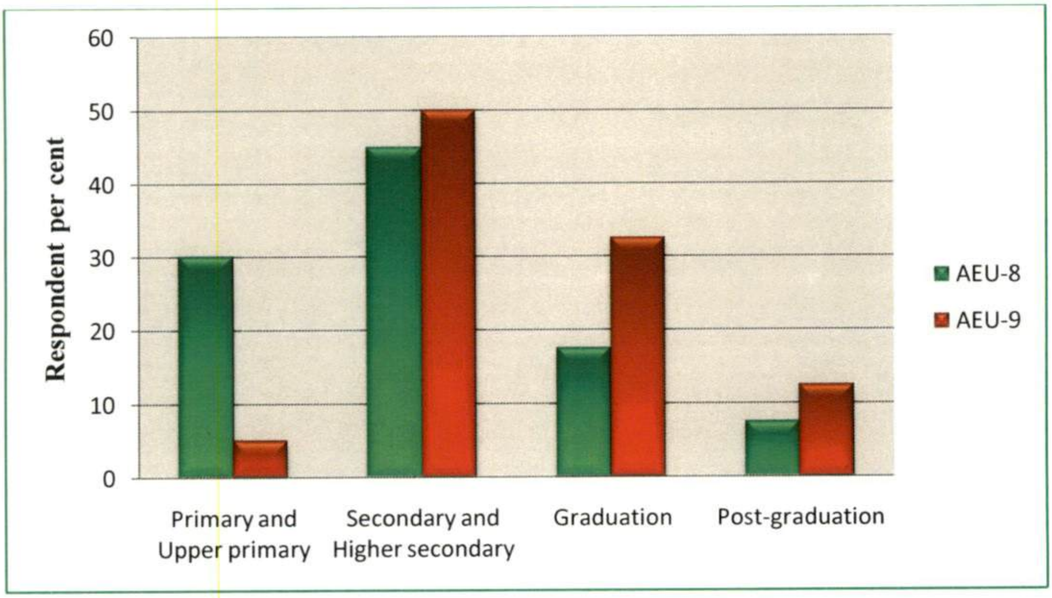


Fig.7. Distribution of respondents according to education

4.1.3 Family size

Table 7. Distribution of respondent farmers according to family size

Sl.No.	Family size	AEU-8 (n=40)	AEU-9 (n=40)	Total (n=80)
		Frequency	Frequency	Frequency
1	Small (< 5.00)	15(37.50)	12(30.00)	27(33.75)
2	Medium(5.00 - 6.00)	18(45.00)	19(47.50)	37(46.25)
3	Large (>6.00)	7(17.50)	9(22.50)	16(20.00)
Median size		**5**	**5.5**	**5**

Figures in parentheses denote percentage to total

The per cent age distribution of respondents according to family size is presented in table 7. The results of the study revealed that 46.25 per cent of the total respondents had medium family size, 33.75 per cent of respondent family comprised of less than five members whereas 20 per cent of the respondent farmers had more than 6 members (Fig 8). The median family size of the respondents obtained was five.

A same trend was noticed in the distribution pattern of the respondents according to family size in both AEU's. The median family size of AEU 8 was 5 whereas in AEU 9, it was 5.5

Hence, it could be inferred that medium and small family size were prevailed in this region and large families were comparatively lesser which, an indication of the shift towards nuclear families is. The finding of this study is in conformity with the results of work conducted by Priya and Jayashree (2013).

4.1.4 Occupation

Table 8. Distribution of respondent farmers according to occupational status.

Particulars	Agriculture as main	Agriculture as subsidiary	
		Service	Own business
	Frequency	Frequency	Frequency
AEU-8 (n=40)	5 (12.50)	12(30.00)	23 (57.50)
AEU-9 (n=40)	7(17.50)	16 (40.00)	17 (42.50)
Total (n=80)	12(15.00)	28(35.00)	40(50.00)

Figures in parentheses denote percentage to total

It is evident from Table 8 that only 15 per cent of the respondents had primary occupation as agriculture. 85 per cent of the respondent farmers did not depend on agriculture as main source of income, out of which, 50 per cent had other business as main income source of income where 35 per cent were working in service sector.

It was found that only 12.5 per cent and 17.5 per cent of the respondents in AEU8 and AEU9 respectively, had agriculture as their main source of income while majority had agriculture as subsidiary source of income in both agro-ecological units (Fig 9).

Hence, it is concluded that only very few respondents take up agriculture as their primary venture which might be due to low and fluctuating income from the homesteads. The result is in contrary to the findings made by Rahul (2013) but in conformity with the results of studies carried out by Thomas (2004) and Helen and Smitha (2013).

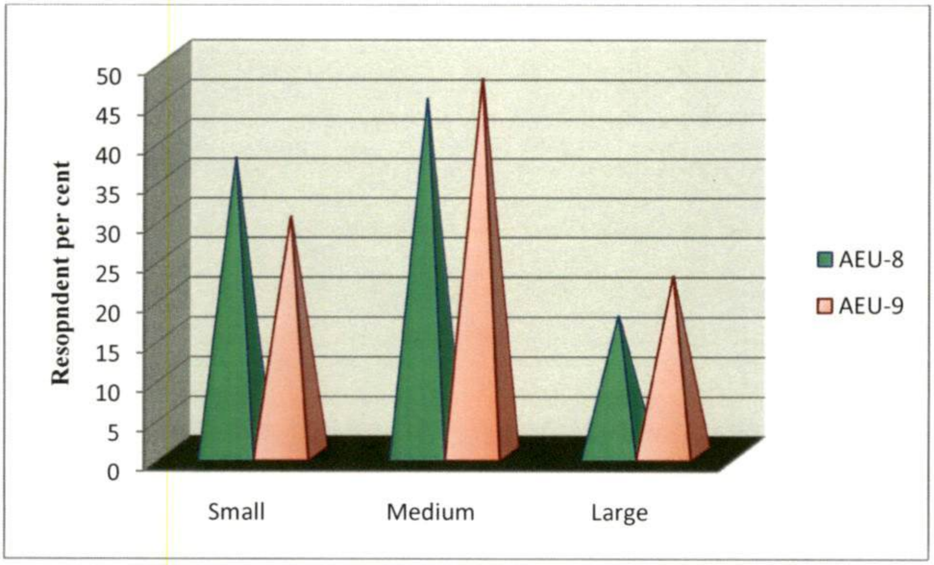


Fig. 8. Distribution of respondent farmers according to Family size

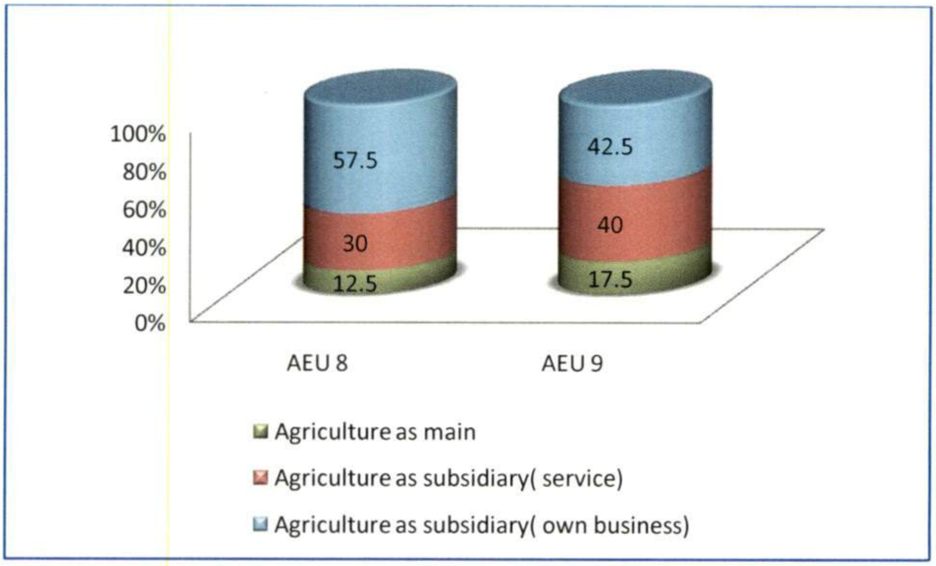


Fig. 9. Distribution of respondents according to occupational status.

4.1.5 Annual Income

Table 9. Distribution of respondent farmers according to annual family income

Income (Rs)	AEU-8 (n=40)	AEU-9 (n=40)	Total (n=80)
	Frequency	Frequency	Frequency
Less than 1 lakh	8(20.00)	5(12.50)	13(16.25)
1-2 lakhs	11(27.50)	13(32.50)	24(30.00)
2-4 lakhs	9(22.50)	16(40.00)	25(31.25)
4-6 lakhs	8(20.00)	3(7.50)	11(13.75)
6-8 lakhs	2(5.00)	2(5.00)	4(5.00)
Above 8 lakhs	2(5.00)	1(2.50)	3(3.75)
Average (Rs.)	2,93,650	2,52,778	2,79,214

Figures in parentheses denote percentage to total

The results presented in Table 9 indicated that cumulatively 77.5 per cent of the respondents had an annual income of less than ₹4 lakhs, and less than 10 per cent of the respondents found to have an annual income above ₹6 lakhs. The overall average annual income estimated was ₹ 2,79,214/-.

27.50 per cent respondents from AEU 8 had annual income in the range of ₹1 lakhs to ₹2 lakh and 22.50 per cent had the same in the range of ₹2 lakhs to ₹4 lakhs. But in AEU 9, 40 per cent of the respondents were observed to have annual income in between ₹2 lakhs - ₹4 lakhs (Fig 10).

4.2 CHARACTERISTICS OF EXISTING HOMESTEADS

Homestead can be defined as the home and its immediate area surrounding owned and occupied by a family unit, and the space used for cultivation and farming etc. Therefore it is important to delineate the features of homesteads in

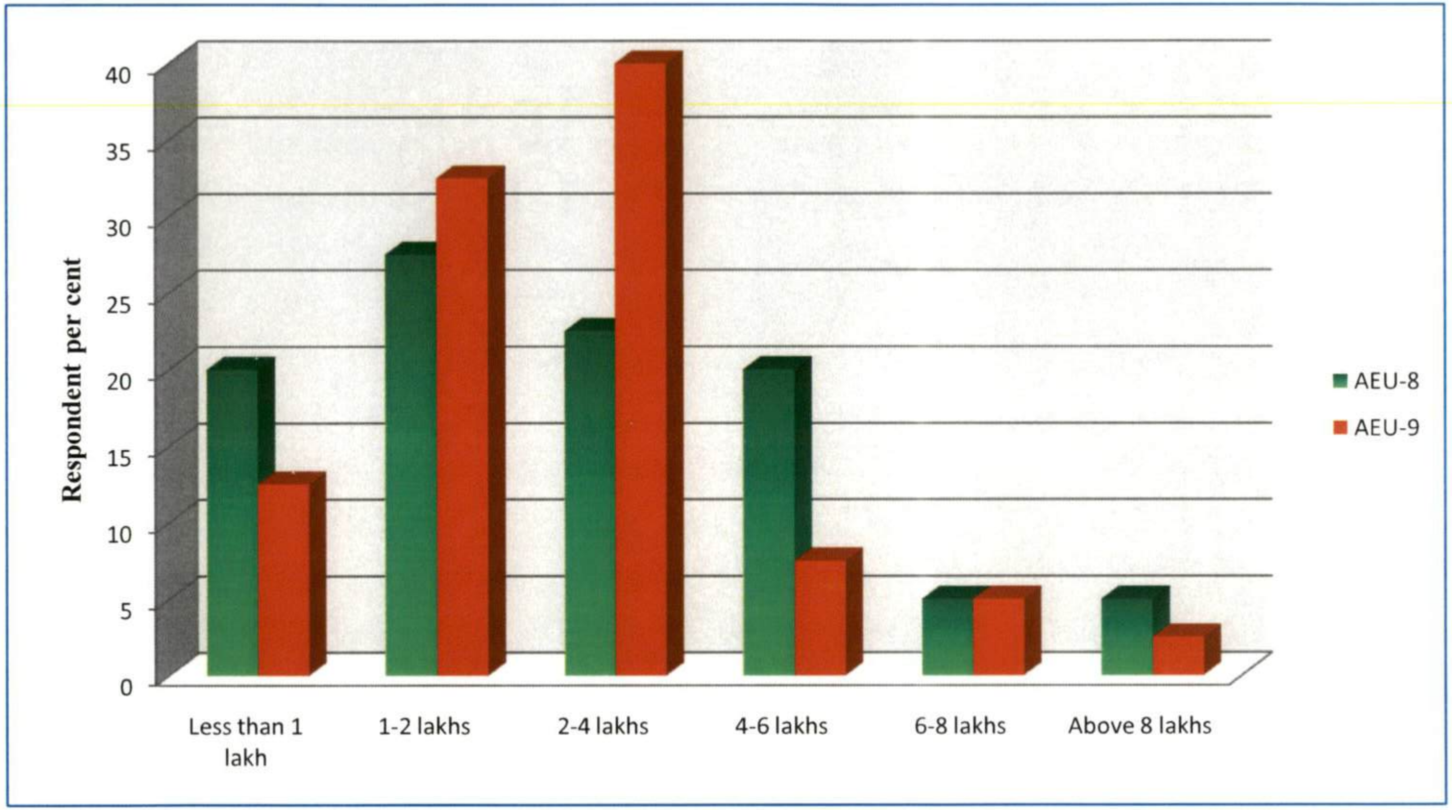


Fig. 10. Distribution of respondents according to annual income

surveyed area and characteristics of the surveyed homesteads are presented in Table 10.

The characteristics of existing homesteads in AEU 8 and AEU 9 and details on farming systems in the homesteads are described below.

4.2.1 Asset details

Table 10. Details on land holding and distribution pattern in homesteads

Size of holding (ha)	AEU-8 (n=40)	AEU-9 (n=40)
0.1-0.2 ha	26(65.00)	18(45.00)
0.2-0.3 ha	14(35.00)	22(55.00)
Total land area	7.19	8.51
Average size	0.18	0.21
Total area of Houses & permanent structures	1.62	1.72
Average area of House & permanent structures	0.040	0.043
Total home garden area	5.57	6.67
Average home garden area	0.14	0.17

Figures in parentheses denote percentage to total

It was found from Table 10 that, 65 per cent of homestead farmers in AEU 8 were having land area of 0.1 to 0.2 ha (25 to 50 cents) whereas, more than fifty per cent of the homestead farmers were observed with land area of 0.2 to 0.3 ha (50 to 75 cents) in AEU 9.

The total land area under homestead was calculated as 7.19 ha and 8.51 ha in AEU 8 and AEU 9 respectively with average holding size of 0.18 ha (45 cents) and 0.21 ha (52.5 cents). Out of the total homestead area, the land available for farming was observed as 5.57 ha and 6.67 ha in AEU 8 and AEU 9 respectively with an average available area of 0.14 ha (35 cents) and 0.17 (42.5 cents) ha respectively. But it was found that most of the space available was found unutilized and the left over space was already occupied by house and permanent structures. The average area used for house and permanent structures was 0.04 ha and 0.043 ha in AEU 8 and AEU 9 respectively.

The details of livestock rearing in the AEU's are given in Table 11 indicated that the number of livestock such as cow, buffalo and goat *etc.* reared were found very less since the maintenance is little difficult. The households as a whole preferred to rear poultry. This could be due to changing consumption habit of people from vegetables to meat and egg.

Table 11. Animal Stock of the homesteads

Particulars	AEU 8	AEU 9
	Frequency	Frequency
Cow	31	25
Buffalo	6	2
Goat	48	35
Poultry	199	172

4.2.2 Farming Practices Adopted in the Homesteads

In AEU 8, rain and wells formed as the prime source of water for cultivation in most of the homesteads (90%), whereas 10 percent of the homestead farmers were solely dependent on rain alone (Fig. 11). The same trend was observed in AEU 9 also, where 92.5 per cent of the farmers were dependent on water from rain and wells and remaining 7.5 per cent on rain alone. The results are in conformity with the reports of John (1997). None of the farmers had modern method of irrigation, such as drip or sprinkler system except two young farmers in AEU 8.

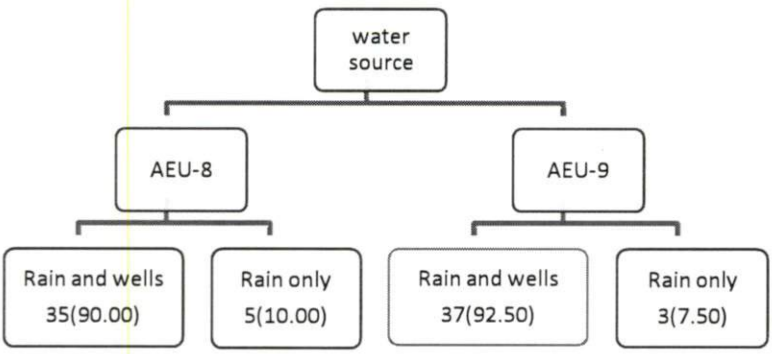


Fig. 11. Source of water for cultivation

As far as irrigation status is concerned, it is clear from the table 12 and Fig 12, that majority of the homesteads in AEU 8 and AEU 9 was semi-irrigated (82.5% and 92.5% respectively). Farmers were noticed to give more preference to intercrops than main crops with respect to irrigation factor.

Table 12. Distribution of farmers based on level of irrigation

Level of irrigation	AEU-8	AEU-9
Fully Irrigated	2(5.00)	0(0.00)
Semi irrigated	33(82.50)	37(92.50)
Rain fed	5(12.50)	3(7.50)

Figures in parentheses denote percentage to total

Data was collected on the usage of manures and fertilizers for various crops and results obtained showed that 72.5 per cent farmers were using organic materials alone and 27.5 per cent farmers were found, using both organic and inorganic materials. The results are in conformity with the report of Balasubramanian and Egli (1986), who reported that majority of the homestead farmers in Nigeria, used organic manures.

With respect to the findings from data collected on plant protection measures, 60 per cent of the farmers were found not adopting any practice to control pests, whereas 23.75 per cent of the farmers seemed to be strictly sticking on organic pest control measures and 16.25 per cent farmers were found using both inorganic and organic pesticides.

Low adoption of plant protection measures might be due to lack of proper awareness and less interest as suggested by Ramesh and Santha (2003). However it was observed that pest and disease incidence in the home garden was relatively lower. John (1997) reported that the plant diversity in homesteads is a well planned strategy to minimize pest and disease attacks.

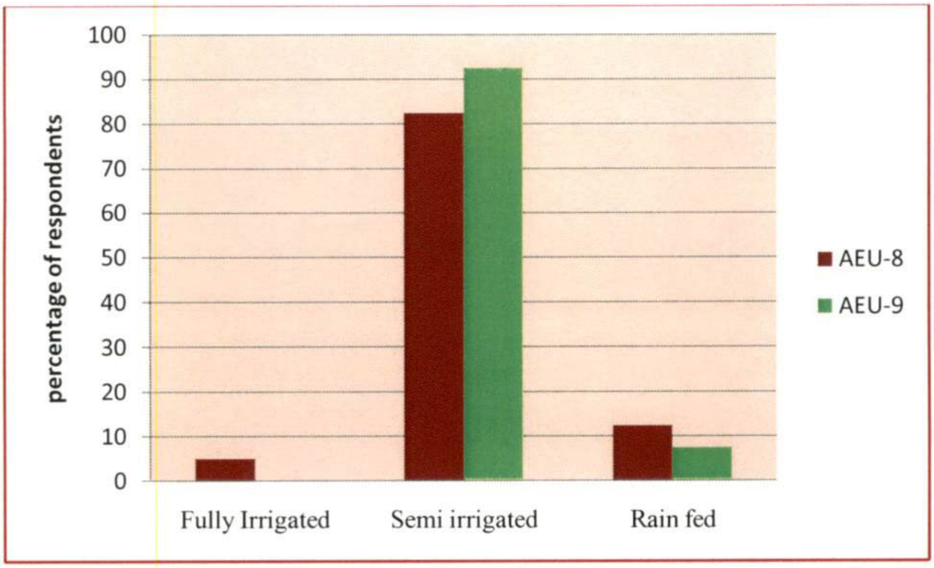


Fig. 12. Distribution of farmers based on level of irrigation

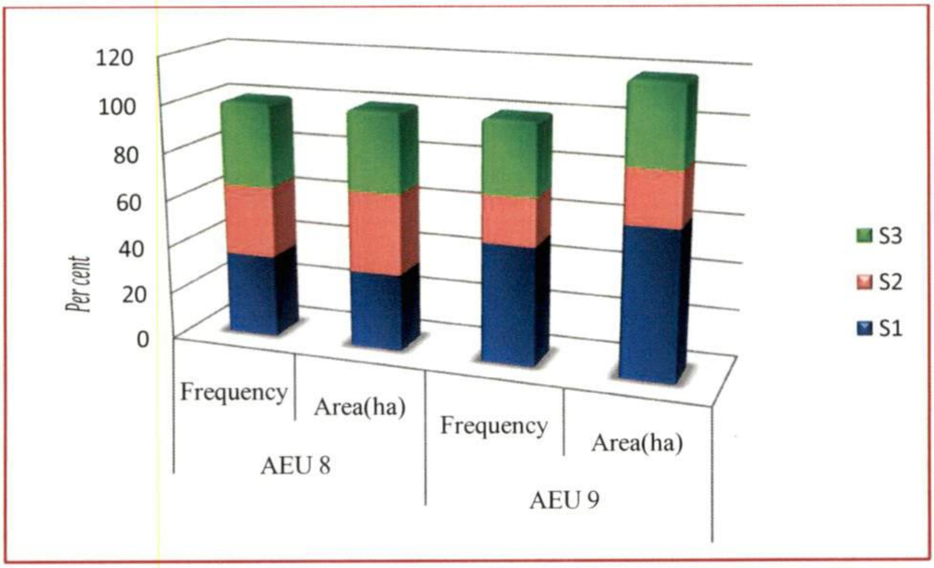


Fig. 13. Cropping/farming systems existing in the homesteads (HFS)

Considering the adoption of varieties of various crops used in the homestead, it was observed that most of the farmers had grown crops as per the availability of seeds/seedling from krishi bhavan and the college of agriculture, Vellayani along with private outlets like Agro bazaar. Both improved and local varieties seemed to be used in the homesteads. Similar results were reported by Salam and Sreekumar (1990).

It was found in majority homesteads (91.25 %), farm activities were carried out by family labour supplemented by hired labour. Besides, a significant contribution was observed from the part of women in the homesteads. Similar view was expressed by Subhadra (2007).

4.2.3 Existing Cropping Pattern of the Homesteads

The selected homesteads were found to be following coconut based cropping system comprising other thirty eight familiar enterprises falling under the groups namely tubers, commercial crops, spices and condiments, stimulants, fruits, vegetables, livestock and poultry and the details are presented in Table 13.

Table 13. Classification of selected enterprises in the homesteads.

Tubers	Tapioca, Colocasia, Dioscorea, Amorphophallus
Commercial crop	Cashew
Spices and condiments	Tamarind, Turmeric, Pepper, Nutmeg, Ginger, Clove
Stimulant	Arecanut
Fruit trees	Annona, Banana, Bilimbi, Guava, Gooseberry, Jack, Mango, Papaya, Sapota, Pineapple
Vegetables	Chilli, Curry leaf, Ladies finger, Bitter guard, Bread fruit , Ivy guard, Moringa, Tomato, Brinjal, Bottle gourd, Long bean, Amaranths
Livestock	Cow, Buffalo and Goat
Poultry	Chickens, Turkeys, Button quail

The selected coconut based homesteads were grouped into three on the basis of cropping/farming system existing in the homesteads (HFS) *viz*, system-I (S_1) consisting of crops alone, system-II (S_2) including crops integrated with poultry or goat or both and system-III (S_3) comprising of crops and cattle with or without poultry and goat.

Table 14. represent the per cent distribution of respondents falling under each HFS along with the share of total area in both AEU's. More or less, same trend was observed in the distribution of number and area under different HFS's in AEU 8 whereas, a domination (50 %) of S_1 HFS was noticed in AEU 9.

Table 14. Cropping/farming systems existing in the homesteads (HFS)

HFS	**AEU 8**			**AEU 9**		
	Frequency	Area(ha)	Average area (ha)	Frequency	Area(ha)	Average area (ha)
S_1	14(35.00)	2.34(32.60)	0.17	20(50.00)	4.49(62.50)	0.22
S_2	12 (30.00)	2.46(34.16)	0.21	8(20.00)	1.63(22.64)	0.20
S_3	14(35.00)	2.39(33.21)	0.17	12(30.00)	2.39(33.18)	0.20
Total	40	7.19	0.18	40	8.51	0.21

Figures in parentheses denote percentage to total

Out of total 40 respondents surveyed, 35 per cent homesteads followed had crops alone, whole 30 per cent had crops + poultry or goat and 35 per cent had crop + cattle ± poultry ± goat (Fig 13). Similar cropping pattern was noticed in AEU 9. The estimated average holding sizes of S_1, S_2 and S_3 were 0.17 ha, 0.21 ha and 0.17 ha in AEU 8 and 0.22 ha, 0.20 ha, 0.20 ha in AEU 9 respectively.

4.2.4 Inventory of Enterprises in the Homesteads of AEU 8

The system was comprised of mainly annual crops, trees, perennial and semi-perennial shrubs. The farmers integrated numerous divergent species, multipurpose trees and shrubs in close association with agricultural crops in most of the homesteads.

The distribution of homestead components/enterprises in S_1, S_2 and S_3 of AEU 8 is presented in Table 15 and their population in terms of minimum and maximum are shown in Table 16. Coconut based homesteads were found to be more prevalent in AEU 8 with significant domination in land use. It was found from Table 14 that all the homesteads (100 %) in AEU 8 had coconut, which suggested that coconut based farming system prevailed in this system. Moreover, from table 15, the estimated average population of coconut palms in homesteads was 20 with a minimum of 4 and maximum of 40 trees. Maximum number of coconut was reported in S_2 followed by S_3 and S_1.

Perennial fruit trees like mango, jack, papaya and annual fruit trees like banana were grown in most of the homesteads (Figure 14). More than 90 per cent of respondents were cultivating banana and mango in their homesteads with average of 58 numbers of trees, and a minimum number of 4 to maximum of 250 plants in a homestead. It was also noticed that homestead farmers preferred different types of fruits including jack fruit (82.5%), papaya (82.5%), sapota (42.5%) etc cultivating in their homesteads. An average of 2 jack fruit tree, 3 mango trees, 7-9 papaya and 2-3 sapota were noticed as a common feature of homesteads. Tapioca was the major tuber crop grown by 82.5 per cent respondents with an average of 147 numbers of plants and it goes up to 500. Tapioca is mainly used for household consumption by all categories of people in Kerala (82.5%). Tapioca was found to be most common and important among the tuber crops, which was cultivated as an intercrop by more than 70 per cent of farmers in homesteads.

Tuber crops were found to be most dominant category and among the tropical tubers, tapioca was noted most in number. Other tuber crops included colocasia, dioscorea and amorphophallus. The predominance of tuber crops in the homesteads may be due to the fact that they can be grown with relatively less care as understorey species in partial shade and yet expected to yield reasonably as suggested by Nair (1993).

The commonly grown vegetables included chilli (55%), amaranthus (47.5%), bread fruit (47.5%), moringa (42.5%) and tomato (40%) which were grown mainly for household consumption. Farmer preference was observed most in crops like banana and pepper. Pepper was grown mostly along with other trees.

Jack fruit tree was common in S_1 (78.57%), S_2 (91.67%) and S_3 (78.57%). Among spices and condiments, black pepper occupied a dominant position in homesteads *viz*; 50 per cent in S_1, 66.67 per cent in $S_2$and 42.86 per cent in S_3. Tapioca was the major tuber crops cultivated in the homesteads 71.43 per cent in S_1, 100 per cent in S_2 and 78.57 per cent in S_3.

The average number of coconut trees in AEU 8 (20) was observed as minimum of 4 to maximum of 40 trees in number. Maximum coconut population was reported in S_2 followed by S_3 and $S_{1.}$

The number of livestock such as cow, buffalo and goat etc. reared were found very less. The households as a whole preferred to rear poultry. This could be due to changing consumption habit of people from vegetables to meat and egg. But combining crop cultivation with livestock activities has positive influence on the betterment of homesteads. Moreover, livestock represents an important capital asset and a source of income to the farmer. Similar views on crop and livestock combination were expressed by Von Maydell (1987) and Helen and Smitha (2013).

4.2.5 Inventory of Enterprises in the Homesteads of AEU 9

The distribution of homestead components/enterprises in S1, S2 and S3 homesteads of AEU 9 is presented in Table 17. The homesteads surveyed in AEU 9 were coconut based and multi-purpose trees like coconut, jack and mango were observed with high frequency (Figure 17:19).

Mixed cropping consisting of coconut, banana, papaya, tapioca and pepper was observed and farmers of AEU 9 were found preferred cultivation of perennial crops along with different intercrops which require less management practices and labour.

Minimum and maximum value in various homestead cropping and farming systems of AEU 8 is also tabulated (Table 18).

Fruit trees commonly grown in AEU 9 were mango (95 %), jack (87.5 %), banana (95 %) and papaya (82.5 %) with an average number of 3 jack trees, 3 mango trees, 59 banana and 7 papaya (Table 18). Cent per cent homesteads in S_1 and 75 per cent homesteads in S_2 had mango and banana, however, cent per cent farmers in S_3 was found growing mango trees. Chilli (70%), tomato (57.5%), amaranthus (52.5) and ladies finger (42.5) were the most commonly growing vegetables in homesteads of AEU 9. More or less similar trend was observed in the pattern of distribution of enterprises in AEU 8 and AEU 9, but comparatively less intensive cultivation was noticed in homesteads. More than 10 different vegetables were observed to be growing in the kitchen yards out of which chilli, tomato, ladies finger and brinjal were found more prevalent. The cultivation of vegetables in homesteads has been reported by Galhena *et al*. (2013).

Crop-livestock integration was observed in 18.5 per cent households, while 15 per cent homesteads preferred poultry rearing along with the crops. The practice of maintaining livestock and poultry components in the homesteads has been reported by Ali (2005) and Andrews (2016).

It is evident from Fig (17 - 19) that 100 per cent of homestead had coconut with an average number of 29 with a minimum of 6 trees to a maximum of 56 trees (Table 18) in AEU 9. It is interesting to observe that, large scale production of ivy guard even though ivy gourd cultivation was not prominent among the homesteads.

Table 15. The distribution of enterprises in S_1, S_2 and S_3 of AEU 8

Enterprise	S_1 (N=14)		S_2 (N=12)		S_3 (N=14)		Overall AEU 8 (N=40)	
	F	P	F	P	F	P	F	P
Coconut	14	100	12	100	14	100	40	100
Jack	11	78.57	11	91.67	11	78.57	33	82.5
Mango	13	92.86	12	100	14	100	39	97.5
Gooseberry	6	42.86	7	58.33	7	50	20	50
Tamarind	7	50	5	41.67	7	50	19	47.5
Bread Fruit	7	50	6	50	6	42.86	19	47.5
Cashew	9	64.29	10	83.33	5	35.71	24	60
Arecanut	4	28.57	3	25	5	35.71	12	30
Tapioca	10	71.43	12	100	11	78.57	33	82.5
Clove	0	0	4	33.33	1	7.14	5	12.5
Banana	13	92.86	12	100	14	100	39	97.5
Nutmeg	0	0	2	16.67	3	21.43	5	12.5
Black pepper	7	50	8	66.67	6	42.86	21	52.5
Ginger	3	21.43	4	33.33	8	57.14	15	37.5
Turmeric	2	14.29	1	8.33	8	57.14	11	27.5
Curry Leaf	2	14.29	7	58.33	6	42.86	15	37.5
Papaya	12	85.71	10	83.33	11	78.57	33	82.5
Moringa	4	28.57	8	66.67	5	35.71	17	42.5
Colocasia	5	35.71	5	41.67	4	28.57	14	35
Dioscorea	1	7.14	5	41.67	3	21.43	9	22.5
Amorphophallus	3	21.43	3	25	2	14.29	8	20
Sapota	5	35.71	7	58.33	5	35.71	17	42.5
Annona	4	28.57	5	41.67	7	50	16	40
Bilimbi	3	21.43	5	41.67	5	35.71	13	32.5
Guava	7	50	9	75	6	42.86	22	55
Pineapple	0	0	1	8.33	1	7.14	2	5
Chilli	8	57.14	7	58.33	7	50	22	55
Ladies Finger	5	35.71	6	50	6	42.86	17	42.5
Bitter Guard	1	7.14	2	16.67	4	28.57	7	17.5
Ivy Guard	3	21.43	2	16.67	5	35.71	10	25
Tomoto	3	21.43	5	41.67	8	57.14	16	40
Brinjal	4	28.57	1	8.33	8	57.14	13	32.5
Bottle Gourd	1	7.14	6	50	2	14.29	9	22.5
Amaranth	6	42.86	5	41.67	8	57.14	19	47.5
Long Bean	4	28.57	1	8.33	5	35.71	10	25
Cow	0	0	0	0	14	100	14	35
Goat	0	0	9	75	3	21.43	12	30
Poulty	0	0	4	33.33	9	64.29	13	32.5

F – Frequency , P – Percentage.

Table 16. Population of enterprises in terms of minimum, average and maximum AEU 8

Enterprise	S_1 (N=14)			S_2 (N=12)			S_3 (N=14)			AEU 8 (N=40)
	Min	Avg.	Max	Min	Avg.	Max	Min	Avg.	Max	weighted avg.
Coconut	10	20	30	4	26	40	5	16	35	20
Jack	1	2	3	1	2	4	1	2	4	2
Mango	1	3	5	1	3	7	1	3	5	3
Gooseberry	1	2	2	1	2	4	1	2	2	2
Tamarind	1	2	3	1	2	3	1	2	3	2
Bread Fruit	1	2	3	1	2	3	1	3	5	2
Cashew	1	2	4	1	3	6	1	3	5	3
Arecanut	1	7	20	2	5	8	2	5	12	6
Tapioca	12	106	400	20	134	500	20	198	420	147
Clove	0	0	0	5	12	16	6	6	6	6
Banana	4	60	250	12	62	200	8	53	150	58
Nutmeg	0	0	0	5	5	5	2	7	15	4
Pepper	2	4	6	1	5	20	2	7	17	5
Ginger	2	4	7	3	8	13	4	11	24	8
Turmeric	7	10	12	4	4	4	4	9	14	8
Curry Leaf	2	3	3	1	2	2	2	3	4	3
Papaya	3	7	13	2	9	20	3	6	10	7
Moringa	1	2	4	1	2	4	1	2	4	2
Colocasia	3	8	14	4	7	12	6	12	20	9
Dioscorea	10	10	10	3	8	12	6	9	13	9
Amorphophallus	5	11	18	4	7	10	6	7	8	8
Sapota	1	2	3	1	2	3	2	3	5	2
Annona	1	2	3	2	2	3	1	2	3	2
Bilimbi	1	2	2	1	2	3	1	1	2	2
Guava	2	2	3	1	3	6	1	2	3	2
Pineapple	0	0	0	10	10	10	400	400	400	143
Chilli	4	10	15	4	12	25	5	15	30	12
Ladies Finger	5	10	15	5	8	14	8	18	25	12
Bitter Gourd	500	500	500	5	128	250	7	62	200	235
Ivy Gourd	8	108	300	6	128	250	4	54	200	95
Tomoto	8	10	12	5	12	30	4	11	20	11
Brinjal	3	7	10	25	25	25	5	9	18	13
Bottle Gourd	50	50	50	8	16	30	2	11	20	26
Amaranth	10	13	20	8	9	10	8	19	50	14
Long Bean	6	13	26	12	12	12	6	17	30	14
Cow	0	0	0	0	0	0	1	3	5	1
Goat	0	0	0	2	4	7	2	3	4	2
Poultry	0	0	0	6	15	25	2	16	45	10

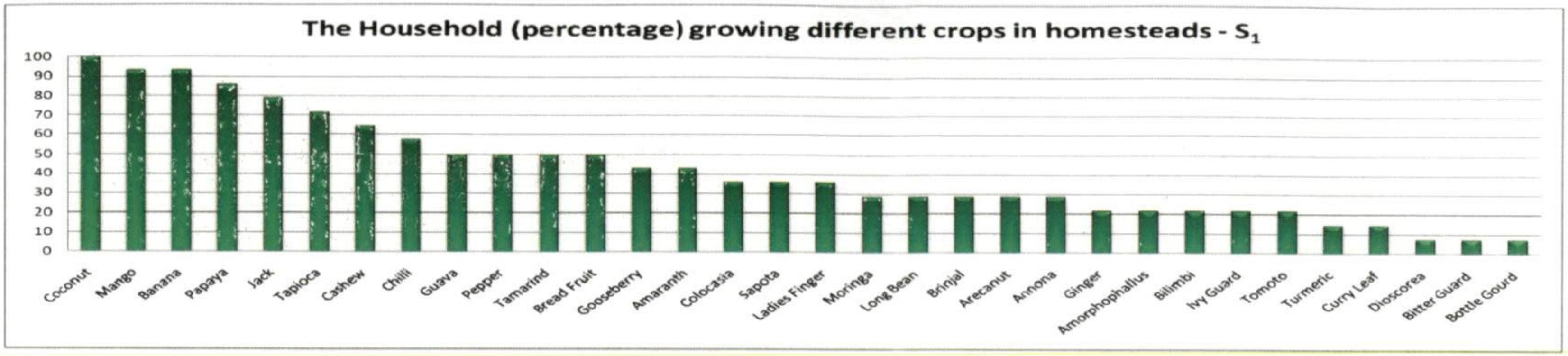


Fig.14. Household (percentage) growing different crops in homesteads AEU 8- S_1

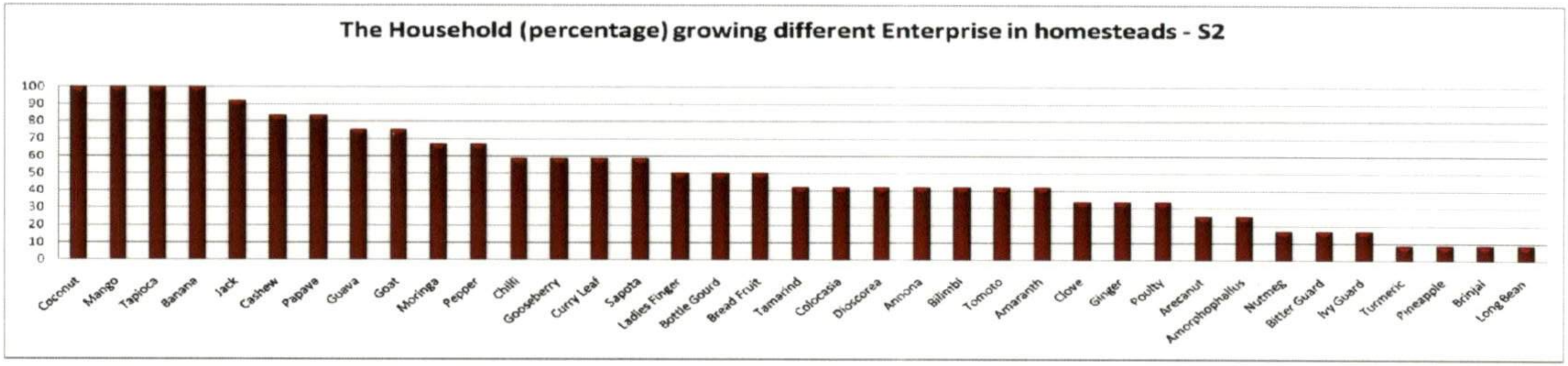


Fig. 15. Household (percentage) containing different enterprise in homesteads AEU 8- S_2

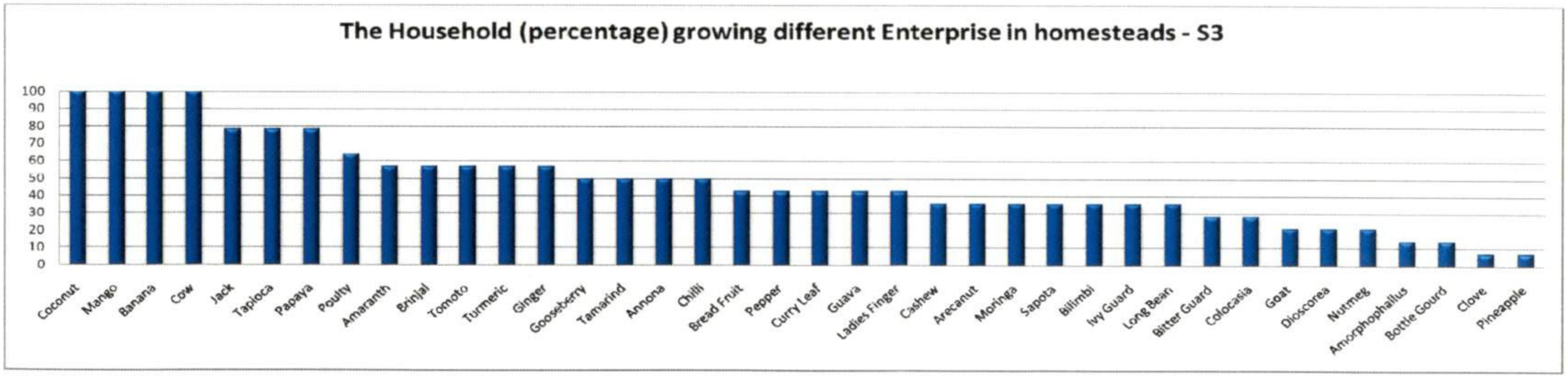


Fig. 16. Household (percentage) containing different enterprise in homesteads AEU 8- S_3

Plate 1. Homestead View – Agro Ecological Unit 8

Table 17. Homestead components and their distribution in AEU 9

Enterprise	S_1 (N=14)		S_2 (N=12)		S_3 (N=14)		Overall AEU 9 (N=40)	
	F	P	F	P	F	P	F	P
Coconut	20	100	8	100	12	100	40	100
Jack	18	90	8	100	9	75	35	87.5
Mango	20	100	6	75	12	100	38	95
Gooseberry	10	50	3	37.5	4	33.33	17	42.5
Tamarind	14	70	3	37.5	5	41.67	22	55
Bread Fruit	9	45	3	37.5	5	41.67	17	42.5
Cashew	9	45	5	62.5	5	41.67	19	47.5
Arecanut	3	15	0	0	4	33.33	7	17.5
Tapioca	13	65	6	75	9	75	28	70
Banana	20	100	7	87.5	10	83.33	37	92.5
Pepper	11	55	5	62.5	9	75	25	62.5
Ginger	6	30	3	37.5	4	33.33	13	32.5
Turmeric	10	50	3	37.5	4	33.33	17	42.5
Curry Leaf	5	25	3	37.5	7	58.33	15	37.5
Papaya	17	85	6	75	10	83.33	33	82.5
Moringa	6	30	3	37.5	7	58.33	16	40
Colocasia	13	65	6	75	7	58.33	26	65
Dioscorea	5	25	4	50	2	16.67	11	27.5
Amorphophallus	10	50	5	62.5	4	33.33	19	47.5
Sapota	8	40	3	37.5	3	25	14	35
Annona	4	20	3	37.5	5	41.67	12	30
Bilimbi	11	55	4	50	5	41.67	20	50
Guava	10	50	3	37.5	7	58.33	20	50
Pineapple	3	15	0	0	2	16.67	5	12.5
Chilli	14	70	7	87.5	7	58.33	28	70
Ladies Finger	8	40	4	50	5	41.67	17	42.5
Bitter Guard	3	15	2	25	4	33.33	9	22.5
Ivy Guard	3	15	2	25	1	8.33	6	15
Tomoto	12	60	4	50	7	58.33	23	57.5
Brinjal	9	45	3	37.5	4	33.33	16	40
Bottle Gourd	1	5	0	0	0	0	1	2.5
Amaranth	12	60	3	37.5	6	50	21	52.5
Long Bean	3	15	2	25	3	25	8	20
Cow	0	0	0	0	12	100	12	30
Goat	0	0	3	37.5	4	33.33	7	17.5
Poultry	0	0	6	75	6	50	12	30

F – Frequency , P – Percentage.

Table 18. Population of enterprises in terms of minimum, average and maximum AEU 9

Enterprise	S_1 (N=20)			S_2 (N=8)			S_3 (N=12)			AEU 8 (N=40)
	Min	Avg	Max	Min	Avg	Max	Min	Avg	Max	weighted average
Coconut	6	30	50	12	27	48	8	29	56	29
Jack	1	3	7	1	3	4	1	3	6	3
Mango	1	3	7	1	3	5	1	2	4	3
Gooseberry	1	2	3	1	2	3	1	2	2	2
Tamarind	1	1	2	1	1	1	1	1	3	1
Bread Fruit	1	2	5	2	2	3	1	2	4	2
Cashew	1	2	5	1	2	2	1	2	3	2
Arecanut	2	11	21	0	0	0	8	11	16	9
Tapioca	15	150	400	40	146	400	12	179	400	158
Banana	5	56	160	10	55	100	16	66	300	59
Pepper	1	7	16	3	4	5	2	9	20	7
Ginger	3	7	10	4	4	4	4	6	8	6
Turmeric	1	5	10	6	6	6	2	9	12	6
Curry Leaf	1	1	2	1	2	3	1	2	3	2
Papaya	1	7	20	2	6	10	1	8	25	7
Moringa	1	1	2	1	1	1	1	2	2	1
Colocasia	3	10	30	15	17	18	2	10	15	11
Dioscorea	3	11	22	6	7	8	3	17	30	12
Amorphophallus	3	8	15	14	15	15	2	9	15	10
Sapota	1	2	3	1	1	2	1	1	2	2
Annona	1	3	4	1	1	2	1	1	2	2
Bilimbi	1	2	4	1	2	3	1	2	3	2
Guava	1	2	5	2	2	2	1	2	2	2
Pineapple	5	8	13	0	0	0	6	9	12	7
Chilli	2	12	30	4	21	40	12	25	40	18
Ladies Finger	5	12	20	8	9	10	5	11	20	11
Bitter Guard	6	27	50	20	25	30	5	62	200	37
Ivy Guard	15	145	400	4	12	20	4	4	4	76
Tomoto	0	8	15	0	6	15	3	7	15	7
Brinjal	4	10	15	5	6	7	6	12	20	10
Bottle Gourd	5	5	5	0	0	0	0	0	0	3
Amaranth	6	16	30	16	18	20	7	15	20	16
Long Bean	5	8	10	8	19	30	3	44	120	21
Cow	0	0	0	0	0	0	1	2	4	1
Goat	0	0	0	3	4	6	2	4	5	2
Poultry	0	0	0	8	15	24	8	19	40	9

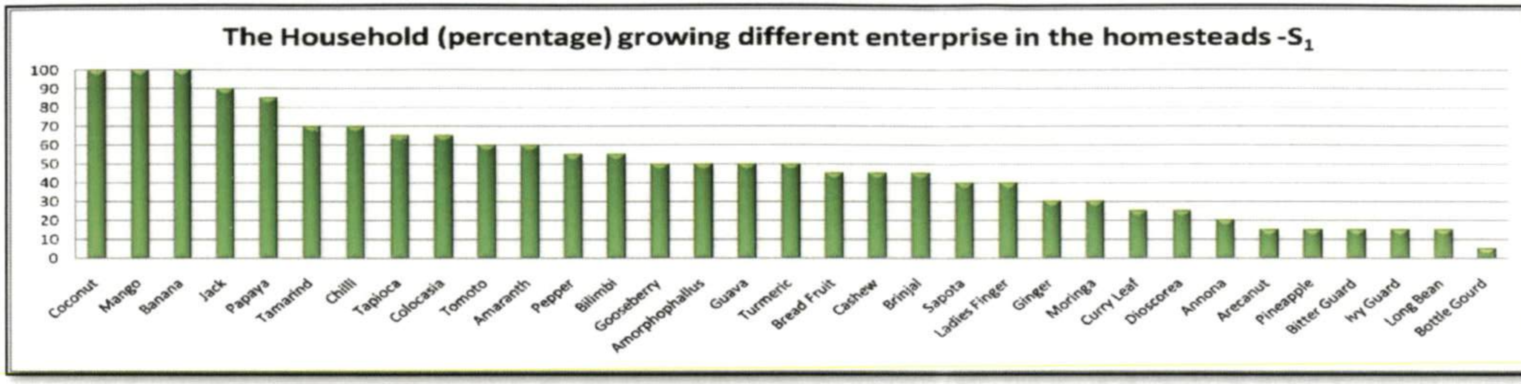


Fig. 17. Household (percentage) growing different crops in homesteads AEU 9- S_1

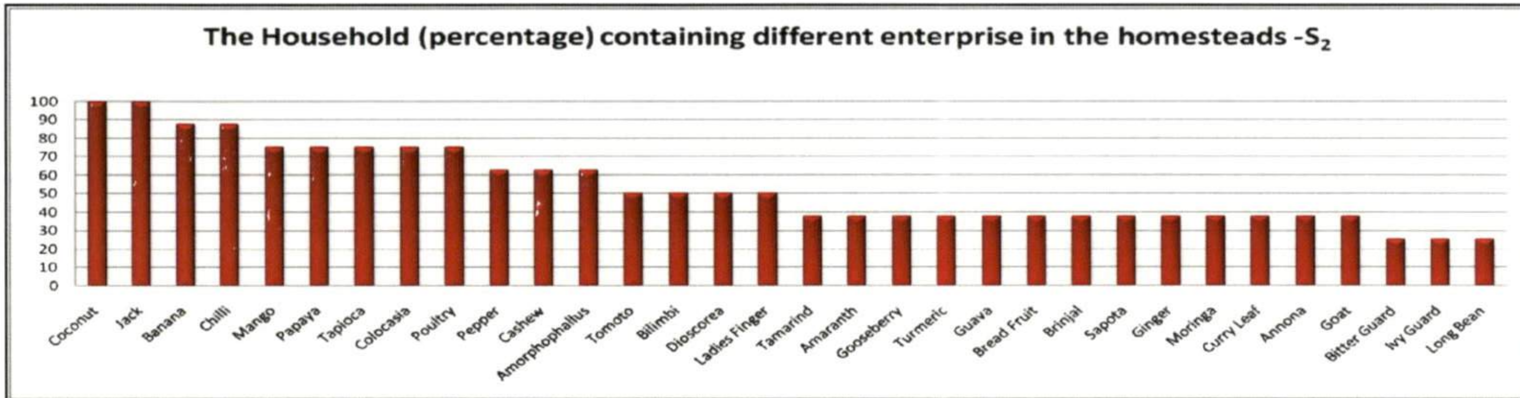


Fig. 18. Household (percentage) containing different enterprise in homesteads AEU 9- S_2

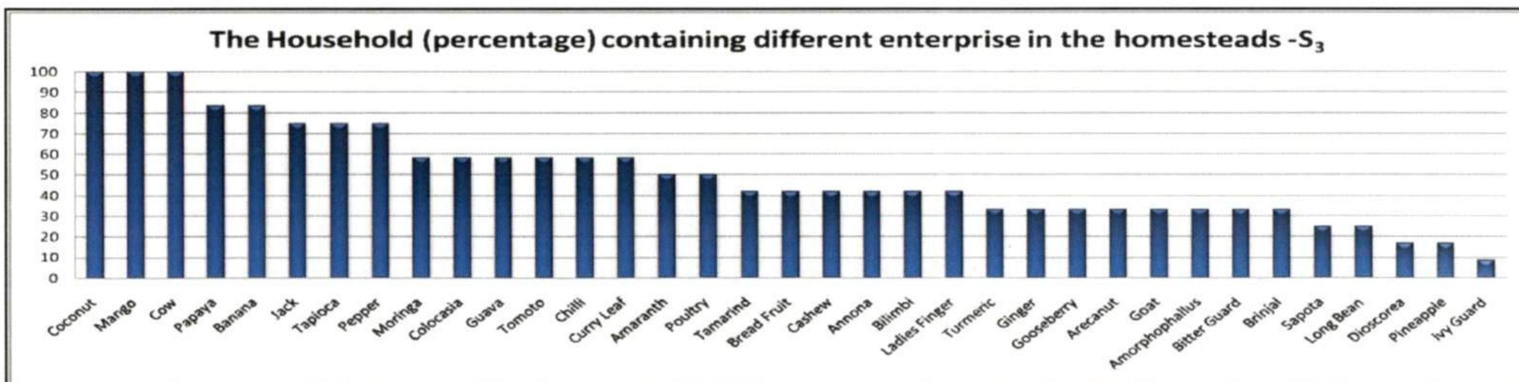


Fig. 19. Household (percentage) containing different enterprise in homesteads AEU 9- S_3

Plate 2. Homestead View – Agro Ecological Unit – 9

4.3 CROPPING/FARMING PATTERN AND ECONOMIC ANALYSIS OF AVERAGE HOMESTEADS.

The average holding size of AEU 8 was worked out by taking total land area under the homesteads in consideration. The economic analysis was done for an average holding size of 1800 m^2 (45 cents) by considering the population of enterprises and is presented in table 19. The average estimated area under house and permanent structures in S_1 was estimated as 378.57 m^2 which left a net cultivated area of 1421.43 m^2. All the homesteads in S_1 had the perennial tree crop coconut with a population of 22 adult bearing palm which constitute almost half (46.73%) of the net cropped area. The farmers used to harvest coconuts in every 3-4 month interval with an average yield of 30 nuts/palm. Fruit trees/crops like jack (2 nos.), mango (3), gooseberry (1), banana (59), sapota (1), guava (1), annona (1) and papaya (7) were found in most of the homesteads which all together constituting 22.13 per cent of the net cultivated area. These fruit trees were sufficient enough to meet the fruit requirement of the family, thereby playing role in the nutritional security of the farm family besides providing substantial contribution to the farm income.

Tapioca, colocasia, amorphophallus, and dioscorea were the major root crops cultivated in the homesteads, which could supply the carbohydrate requirements of the farm family. Moreover, the kitchen garden unit was found to meet the vegetable requirements of the farm family in addition to breadfruit and moringa which constituted 120.73 m^2 area in S_1. Tamarind, pepper, ginger, turmeric and curry leaf were expected to meet the daily requirement of spices in the household.

The total investment amount for average homestead of size, 45 cents was ₹24862.78/- out of which 66.99 per cent was spent as labour charge (both family and hired labour) and 27.22 per cent as input material cost (Fig.20). 43.12 per cent of the total expenditure was used for banana cultivation followed by coconut (16.64 %). The gross and net returns for an average homestead of S_1 were worked out as ₹52458.98/-

and ₹27596.2/-, respectively, resulting a benefit: cost ratio of 2.11 (Table 19). Among the different enterprises, the maximum net return (₹11238.04) was obtained from banana cultivation in an area of 141.84 m^2 followed by vegetable cultivation in 40 m^2 area (₹3647.55), while the B: C ratio was highest for gooseberry (3.51) arecanut (3.19) and jack (3.14). The B:C ratio of coconut was only 1.76 but most of the homesteads contained more than 15 number of palms due to its importance in the household purposes.

The average homestead size was worked out as 45 cents (1800 m^2). The average area under house and permanent structure in S_2 was 372 m^2. Economic analysis was done for an average cropping area of 1428 m^2 and the result is presented in table 20. S_2 homestead farming system in AEU 8 was comprised of either poultry or goat or combination of both, in addition to crops in S_1. Net cultivated area of 23.46 per cent area was covered by 23 adult bearing coconut palms. Fruit trees/crops like jack (2 nos.), mango (3), gooseberry (1), banana (55), sapota (1), guava (2), annona (1), pineapple (1) and papaya (7) were found, all together constituting 16.23 per cent of the net cultivated area.

Table 19. Economic analysis – HFS S_1-AEU 8 -average farm size of 45 cents

Sl.No	Enterprise	Population	Input Cost (₹)	Labour Cost (₹)	Other Expenses (₹)	Total Expenditure (₹)	Gross Return (₹)	Net Return (₹)	B:C Ratio
1	Coconut	22 nos.	1183.34	2845.9	107.51	4136.75	7265.04	3128.29	1.76
2	Jack	2 nos.	-	326.75	83.76	410.51	1287	876.49	3.14
3	Mango	3 nos.	42.95	744.88	115.19	903.02	2123.02	1220	2.35
4	Gooseberry	1 no.	19.11	133.45	23.04	175.59	616.04	440.45	3.51
5	Tamarind	1 no.	-	191.98	53.75	245.73	762.88	517.15	3.1
6	Bread Fruit	1 no.	-	144.3	-	144.3	383.96	239.66	2.66
7	Cashew	1 no.	15.36	422.35	-	437.71	923.04	485.32	2.11
8	Arecanut	2 nos.	76.79	165.1	15.36	257.25	821.67	564.42	3.19
9	Tapioca	81 nos.	1009.04	1274.74	314.85	2598.63	5483.2	2884.57	2.11
10	Banana	59 nos.	3102.83	7049.49	568.26	10720.58	21958.62	11238.04	2.05
11	Pepper	2 nos.	-	249.57	-	249.57	695.88	446.3	2.79
12	Ginger	1 no.	5	-	-	5	12.22	7.22	2.44
13	Turmeric	1 no.	9.25	-	-	9.25	15.36	6.11	1.66
14	Papaya	7 nos.	263.23	145.9	46.08	455.21	1082.76	627.55	2.38
15	Moringa	1 no.	3.46	19.68	-	23.13	59.93	36.8	2.59
16	Colocasia	3 nos.	31.62	35.4	-	67.02	122.87	55.85	1.83
17	Dioscorea	1 no.	9.98	17.75	-	27.74	61.43	33.7	2.21
18	Amorphophallus	3 nos.	28.01	70.01	-	98.02	282.21	184.19	2.88
19	Sapota	1 no.	14.56	161.26	-	175.82	318.69	142.86	1.81
20	Annona	1 no.	18.4	171.76	-	190.16	445.39	255.23	2.34
21	Guava	1 no.	11.35	360.92	-	372.27	930.72	558.45	2.5
22	Vegetables	1 unit	922.46	2123.62	113.42	3159.5	6807.06	3647.55	2.15
Total			6766.74	16654.83	1441.21	24862.78	52458.98	27596.2	2.11

Among the tuber crops, colocasia, amorphophallus, tapioca and dioscorea, tapioca was cultivated more in number (118 nos.) in comparison with other tubers. The preference towards tuber crops especially for tapioca might be because of less requirements of hired labour for management practices. Tuber crops were observed as common staple food with year round market demand. Vegetable requirement of the family was met from kitchen yards maintained in an average area of 26 m^2. Clove and nutmeg were the other trees found in the average homesteads, in addition to spices found in S_1. The homestead had 3 unit of goats and 4 units of poultry. The most income generating enterprise in the homestead was goat unit attributed mainly to the sale of kids. Poultry unit was maintained in S_2 mainly to meet the egg and meat requirement of the farm family.

The total investment in average homestead of S_2 was ₹48529.84/- out of which 43.86 per cent was spent as labour charge (both family and hired labour) and 52.94 per cent for hiring input materials including seeds, fertilizer and plant protection chemical etc. (Fig.20). It is observed that 45.73 per cent of the total expenditure was spent over goat and poultry rearing which contributed 48.36 per cent of the total net income. The gross and net returns from average homestead of S_2 worked out was ₹103774.31/- and ₹55244.5/- respectively, resulting a benefit: cost ratio of 2.14 (Table 20). Among the different crop enterprises, the maximum net return (₹8830.4) was obtained from banana cultivation followed by tapioca (₹4080.15), while the B: C ratio was highest for jack (3.64) and clove (3.05). The B: C ratio of coconut was least in S_2 also which might be due to less productivity and high cost of harvesting. However, the benefit cost ratio was 2.41 and 1.61 for goat and poultry respectively, indicating high expenditure incurred in maintaining these units compared to crop enterprises.

Table 20. Economic Analysis – HFS S_2-AEU 8 -Average farm size of 45 cents

Sl.No	Enterprise	Population	Input Cost (₹)	Labour Cost (₹)	Other Expenses (₹)	Total Expenditure (₹)	Gross Return (₹)	Net Return (₹)	B:C Ratio
1	Coconut	23nos.	648	3553.33	150.24	4351.58	7945.58	3594	1.83
2	Jack	2nos.	-	533.4	98.33	631.73	2302.3	1670.57	3.64
3	Mango	3nos.	-	608.33	73.29	681.62	1987.83	1306.21	2.92
4	Gooseberry	1no.	7.38	158.33	36.64	202.36	448.53	246.18	2.22
5	Tamarind	1no.	-	276.55	21.99	298.54	881.65	583.11	2.95
6	Bread Fruit	1no.	-	166.32	-	166.32	420.33	254.01	2.53
7	Cashew	2nos.	-	766.67	14.66	781.32	1506.84	725.52	1.93
8	Arecanut	1no.	-	134.43	29.32	163.75	384.77	221.03	2.35
9	Tapioca	118 nos.	1375.9	2066.77	439.74	3882.41	7962.56	4080.15	2.05
10	Clove	3 nos.	142.35	541.67	65.96	749.98	2286.64	1536.67	3.05
11	Banana	55 nos.	3610.75	5258.36	337.13	9206.24	18036.64	8830.4	1.96
12	Nutmeg	1 no.	23.32	283.34	73.29	379.95	879.48	499.53	2.31
13	Pepper	3 nos.	9.83	350.63	-	360.46	961.16	600.7	2.67
14	Ginger	2 nos.	14.8	-	-	14.8	29.13	14.33	1.97
16	Curry Leaf	1 no.	3.22	16.5	-	19.72	71.25	51.53	3.61
17	Papaya	7 nos.	274.34	170.83	117.26	562.44	1289.9	727.47	2.29
18	Moringa	1 no.	5.57	56.25	-	61.82	131.61	69.79	2.13
19	Colocasia	2 nos.	35.77	39.44	-	75.21	109.93	34.73	1.46
20	Dioscorea	3 nos.	35.69	55.26	-	90.95	170.03	79.08	1.87
21	Amorphophallus	1 no.	21.99	40.94	-	62.93	205.21	142.28	3.26
22	Sapota	1 no.	19.58	184.5	-	204.08	406.76	202.68	1.99
23	Annona	1 no.	7.3	254.81	-	262.11	513.03	250.92	1.96
24	Bilimbi	1 no.	-	37.22	-	37.22	107.74	70.52	2.89
25	Guava	2 nos.	9.56	491.67	-	501.23	1042.18	540.96	2.08
26	Pineapple	1 no.	5.06	8.33	-	13.39	29.43	16.04	2.2
27	Vegetables	1 unit.	773.75	1703.43	99.45	2576.63	4757.57	2180.94	1.85
28	Goat	3 unit	14165.45	2325.6	-	16491.05	39745.54	23254.49	2.41
29	Poultry	4 unit	4500	1200	-	5700	9160.67	3460.67	1.61
Total			25689.61	21282.91	1557.32	48529.84	103774.31	55244.5	2.14

S_3 farming system in AEU 8 comprised of S_2 + cattle unit with the average homestead size of 45 cents (1800 m^2). The average area under house and permanent structures was 438.69 m^2, with 1361.31 m^2 area as net cropping area. Coconut, tapioca and banana together constituted 39.74 per cent of the total cultivated area. Fruit trees/crops like jack (1 nos.), mango (3), gooseberry (1), banana (56), sapota (1), guava (1), annona (1), pineapple (30) and papaya (5) were cultivated which were sufficient enough to meet the fruit requirement of the family, in addition to generation of farm income.

Tapioca was observed as the most predominant crop in the homestead (164 nos.) and other tuber crops cultivated were colocasia, amorphophallus and dioscorea. Around 46.5 m^2 area in the kitchen yard was employed for vegetable cultivation. Tamarind, pepper, ginger, nutmeg, turmeric and curry leaf met spice requirement. Cashew (1 nos.), the export oriented crop was grown in the homesteads and arecanut palm (3 nos.) was noticed as the main masticatory nut.

The livestock/poultry components of S_3 comprised of three cattle unit, one goat and ten poultry units. The livestock system not only ensured enterprise diversification, but also augmented farm income by the sale of surplus milk and eggs. The interaction between the crop and livestock system of the model facilitated a high degree of organic recycling between the systems.

The total investment worked out was ₹168905.4/- out of which 27.03 per cent was used to meet labour charge (both family and hired labour) and 71.57 per cent for meeting input materials cost (Fig.20). It is evident from the table that 73.09 per cent of the total expenditure was used for cattle rearing which contributed 70.8 per cent of the total net income. The gross and net returns from the average homestead of S_2 were estimated as ₹341150.89/- and ₹341150.89/- respectively contributing a benefit: cost ratio of 2.02 (Table21).

Table 21. Economic Analysis – HFS S_3-AEU 8 -Average farm size of 45 cents

Sl.No.	Enterprise	Population	Input Cost (₹)	Labour Cost (₹)	Other Expenses (₹)	Total Expenditure (₹)	Gross Return (₹)	Net Return (₹)	B:C Ratio
1	Coconut	17 nos.	1108.79	1637.8	147.74	2894.33	5656.73	2762.4	1.95
2	Jack	1 no.	-	352.56	-	352.56	1075.38	722.82	3.05
3	Mango	3 nos.	12.6	727.39	97.99	837.98	2085.53	1247.55	2.49
4	Gooseberry	1 no.	-	102.91	0	102.91	388.94	286.03	3.78
5	Tamarind	1 no.	-	97.99	30.15	128.14	509.55	381.41	3.98
6	Bread Fruit	1 no.	-	153.53	37.69	191.22	481.21	289.99	2.52
7	Cashew	1 no.	-	252.51	67.84	320.35	643.72	323.37	2.01
8	Arecanut	2 nos.	37.84	156.41	52.76	247.01	672.36	425.35	2.72
9	Tapioca	164 nos.	2493.02	2555.28	505.03	5553.32	12143.22	6589.89	2.19
10	Banana	56 nos.	3013.86	6007.54	595.48	9616.88	18936.53	9319.65	1.97
11	Nutmeg	2 nos.	72.65	950.77	75.38	1098.79	3165.83	2067.04	2.88
12	Pepper	3 nos.	19.24	399.5	101.38	520.12	1317.59	797.47	2.53
13	Ginger	6 nos.	20.39	-	-	20.39	58.34	37.95	2.86
14	Turmeric	5 nos.	32.94	-	-	32.94	56.98	24.05	1.73
15	Curry Leaf	1 no.	-	32.91	-	32.91	89.4	56.5	2.72
16	Papaya	5 nos.	219.47	124.37	-	343.84	874.37	530.53	2.54
17	Moringa	1no.	-	17.88	-	17.88	77.45	59.57	4.33
18	Colocasia	4 nos.	39.3	27.75	-	67.05	135.68	68.63	2.02
19	Dioscorea	2nos.	16.03	42.75	-	58.78	135.68	76.89	2.31
20	Amorphophallus	1 no.	15.83	31.43	-	47.26	131.91	84.65	2.79
21	Sapota	1 no.	7.61	173.37	-	180.98	320.35	139.37	1.77
22	Annona	1 no.	5.44	286.15	-	291.59	731.16	439.57	2.51
23	Bilimbi	1 no.	-	37.74	-	37.74	86.16	48.42	2.28
24	Guava	1 no.	11.76	248.74	-	260.5	678.39	417.89	2.6
25	Pineapple	30 nos.	165.52	113.07	75.38	353.96	753.77	399.81	2.13
26	Vegetables	1 unit.	1410.82	2241.93	198.99	3851.75	8730.99	4879.24	2.27
27	Cattle	3 nos.	97987.58	25100	368.33	123455.91	245400	121944.09	1.99
28	Goat	1 no.	6061.74	1985.6	-	8047.34	17000	8952.66	2.11
29	Poultry	10 nos.	8139.73	1801.23	-	9940.96	18813.67	8872.71	1.89
Total			120892.16	45659.11	2354.14	168905.4	341150.89	172245.49	2.02

The contribution of livestock to the net farm income was higher than that from the other components while the B: C ratio was highest for moringa (4.33) and tamarind (3.98). The B: C ratio of jack, gooseberry was also found to be more than 3 whereas, it was low for coconut (1.9). Banana and tapioca contributed 5.41 and 3.83 percent to the total net returns in S_3 which is meager as compared to S_1 and S_2 in AEU 8.

As observed in AEU 8, in homestead cropping system S_1 of AEU 9, coconut was the major perennial crop observed with 28 adult bearing palms which alone constituted almost half of the net cultivated area (46.55). Harvesting was done in every 3 month interval from which average yield of 19 nuts/palm was obtained. Jack (2 nos.), mango (3), gooseberry (1), banana (52), sapota (1), guava(1), pineapple (1) and papaya (6) were noticed all together occupying 13.70 per cent of the net cultivated area.

Tapioca, colocasia, amorphophallus, and dioscorea were the staple food crops which could meet the carbohydrate requirements of the farm family. The kitchen garden unit in addition to breadfruit, bilimbi and moringa was found sufficient to meet the vegetable requirements of the farm family. Tamarind, pepper, ginger, turmeric and curry leaf provided the spices needed for the household. The export oriented cash crop, cashew (1 nos.) and the masticatory nut crop, arecanut palm (2 nos.) were also grown in the homesteads.

An average area of 394.86 m^2 was occupied by house and permanent structures, resulting a net average cropping area of 1405.14 m^2. The total investment was ₹20376.39/- out of which 65.43 per cent was used as labour charge (both family and hired labour) and 30 per cent as input cost (Fig.21). It was noticed that 43.01 per cent of the total expenditure was spent for growing banana. The gross and net returns from average homestead of S_1 were worked out as ₹43679.34/- and ₹23302.9/- respectively resulting in a benefit: cost ratio of 2.14 (Table 22).

Table 22. Economic Analysis – HFS S_1-AEU 9 -Average farm of 52.5 cents

Sl.No	Enterprise	Population	Input Cost (₹)	Labour Cost (₹)	Other Expenses (₹)	Total Expenditure (₹)	Gross Return (₹)	Net Return (₹)	B:C Ratio
1	Coconut	28 nos.	984.04	2450.86	56.07	3490.97	6424.75	2933.78	1.84
2	Jack	2 nos.	0	446.43	-	446.43	1585.35	1138.92	3.55
3	Mango	3 nos.	47.76	682.44	98.13	828.33	2516.76	1688.43	3.04
4	Gooseberry	1 no.	9.35	100.97	-	110.32	346.71	236.39	3.14
5	Tamarind	1 no.	-	190.19	-	190.19	634.02	443.83	3.33
6	Bread Fruit	1 no.	-	98.67	9.35	108.02	367.99	259.97	3.41
7	Cashew	1 no.	13.36	184.58	18.69	216.63	405.61	188.98	1.87
8	Arecanut	2 nos.	7.71	252.34	9.35	269.39	551.4	282.01	2.05
9	Tapioca	91 nos.	1359.05	925.23	210.28	2494.56	5975.63	3481.06	2.4
10	Banana	52 nos.	2940.08	5371	453.27	8764.35	17509.43	8745.08	2
11	Pepper	4 nos.	-	476.39	-	476.39	1381.3	904.91	2.9
12	Ginger	2 nos.	9.16	11.23	-	20.39	38.9	18.51	1.91
13	Turmeric	3 nos.	11.82	-	-	11.82	30.84	19.02	2.61
14	Papaya	6 nos.	208.68	98.13	60.75	367.56	830.14	462.58	2.26
15	Colocasia	6 nos.	74.81	22.45	-	97.26	153.27	56.01	1.58
16	Dioscorea	3 nos.	23.08	15.54	-	38.62	65.42	26.8	1.69
17	Amorphophallus	4 nos.	30.14	88.79	-	118.93	343.46	224.53	2.89
18	Sapota	1 no.	11.83	172.9	-	184.73	414.42	229.69	2.24
19	Bilimbi	1 no.	-	40.65	-	40.65	95.7	55.05	2.35
20	Guava	1 no.	6.64	142.52	14.02	163.18	414.95	251.77	2.54
21	Pineapple	1 no.	7.02	11.68	-	18.7	35.05	16.34	1.87
22	Vegetables	1 unit	369.81	1549.16	-	1918.97	3558.24	1639.27	1.85
Total			6114.34	13332.15	929.91	20376.39	43679.34	23302.9	2.14

Among the different enterprises, the maximum net return (₹8745.08) was obtained from banana cultivation followed by tapioca (₹8745.08), while the B: C ratio was highest for jack (3.55) and tamarind (3.13).

S_2 homesteads in AEU 9 were found engaged with either poultry or goat or combination of both along with the crops. Coconut palms (15 nos.) covered 40 per cent of net cultivated area. Fruit trees/crops like jack (2 nos.), mango (2), banana (35), guava (1), annona (1) and papaya (3) were noticed occupying 23 per cent of the net cultivated area.

Tuber crops grown were colocasia, amorphophallus, tapioca and dioscorea but were less in number in comparison with that in other farming systems in AEU 9. Kitchen yards maintained in an area of 20 m^2 was sufficient in meeting the vegetable requirement of the family. Goats (3 units) and poultry (8 units) were observed in the homestead where goat was the maximum income generating enterprise attributed to the sale of kids. Poultry unit was found mainly to meet egg and meat requirement of the farm family.

The average area occupied by house and permanent structure in the homestead was 434.71 m^2, with net average cropping area of 1365.29 m^2. The total investment was ₹34357.52/- out of which 63.88 per cent was spent as labour charge (both family and hired labour) and 33.81 per cent as input cost (Fig.21). It was observed that 66.55 per cent of the total expenditure was used for rearing goat and poultry which contributed 70.89 per cent of the total net income. The gross and net returns from average homestead of S_2 was worked out as ₹68629.3/- and ₹34271.78/- respectively, contributing a benefit: cost ratio of 2 (Table 23). Among the different crop enterprises, the maximum net return (₹5244.4) was gained from banana cultivation followed by coconut (₹1486.64) whereas, the B: C ratio was the highest for jack (3.48) and pepper (3.1).

Table 23. Economic Analysis – HFS S_2-AEU 9 -Average farm size of 52.5 cents

Sl.No	Enterprise	Population	Input Cost (₹)	Labour Cost (₹)	Other Expenses (₹)	Total Expenditure (₹)	Gross Return (₹)	Net Return (₹)	B:C Ratio
1	Coconut	15 nos.	346.65	1309.28	162.87	1818.79	3305.44	1486.64	1.82
2	Jack	2 nos.	-	97.38	-	97.38	339.25	241.87	3.48
3	Mango	2 nos.	9.35	789.43	64.5	863.28	1538.33	675.05	1.78
4	Cashew	1 no.	-	148.34	-	148.34	296.68	148.34	2.00
5	Tapioca	39 nos.	437.83	606.27	132.18	1176.28	2412.16	1235.89	2.05
6	Banana	35 nos.	1695.4	3482.8	412.78	5590.98	10835.38	5244.4	1.94
7	Pepper	1 no.	7.75	67.09	-	74.84	232.19	157.35	3.10
8	Turmeric	1 no.	5.42	-	-	5.42	15.48	10.06	2.86
9	Curry Leaf	1 no.	-	15.29	-	15.29	45.15	29.86	2.95
10	Papaya	3 nos.	141.89	51.6	12.9	206.39	396.65	190.26	1.92
11	Colocasia	6 nos.	63.85	38.7	-	102.55	219.29	116.74	2.14
12	Dioscorea	1 no.	10.06	17.31	-	27.37	41.28	13.91	1.51
13	Amorphophallus	2 no.	29.02	128.99	-	158.02	316.03	158.02	2.00
14	Annona	1 no.	16.11	84.8	-	100.91	270.88	169.98	2.68
15	Bilimbi	1 no.	-	18.81	-	18.81	48.37	29.56	2.57
16	Guava	1 no.	10.32	120.93	-	131.25	255.41	124.16	1.95
17	Vegetables	30 unit	157.2	800.89	0.26	958.35	1903.29	944.94	1.99
18	Goat	3 unit	14780.9	2487.9	7.87	17276.66	36012.45	18735.79	2.08
19	Poultry	8 unit	4234.54	1352.09	-	5586.63	11145.64	5559.01	2.00
Total			21946.3	11617.9	793.35	34357.52	68629.3	34271.78	2.00

S_3 farming system of AEU 8 was comprised of S_2 + cattle unit. Adult bearing coconut (31 nos.) constituted 37.28 per cent of the total cultivated area. Fruit trees/crops like jack (2 nos.), mango (2), gooseberry (1), banana (58), guava (1), annona (1), pineapple (2) and papaya (7) were found grown which could meet the nutritional requirement of the family, besides providing farm income.

Tapioca was the most predominant crop in the homestead (140 nos.) and other tuber crops noticed were colocasia, amorphophallus and dioscorea. An area of around 1 cent in the kitchen yard was engaged with vegetable cultivation. Tamarind, pepper, ginger, turmeric and curry leaf were the spices observed in the homestead.

The livestock/poultry components of the model comprised of two cattle, one goat and ten poultry units. Besides ensuring enterprise diversification, the livestock system could increase farm income by way of selling surplus milk and eggs. The interaction between crop and livestock system of the model facilitated a high degree of organic recycling between the systems. Continuous addition of organic manures from the livestock system was observed helpful in maintaining soil health and to sustain the productivity.

An average area of 443.59 m^2 was occupied by house and permanent structures resulting a net average cropping area of 1356.41 m^2.The total investment was ₹122756.1/- out of which 38.03 per cent was utilized for providing labour charge (both family and hired labour) and 61.06 per cent as input cost (Fig. 21). It was observed that 68.82 per cent of the total expenditure was used for cattle rearing from which 67.7 per cent of the total net income was generated. The gross and net returns from average homestead of S_2 was worked out as ₹254271.7/- and ₹131516/-, resulting in a benefit: cost ratio of 2.07(Table 24). The contribution of livestock to the net farm income was higher than that from other components while the B:C ratio was the highest for bread fruit (3.51) and pepper (3.44).

Table 24. Economic Analysis – HFS S_3-AEU 9 -Average farm of 52.5 cents

Sl.No	Enterprise	Population	Input Cost (₹)	Labour Cost (₹)	Other Expenses (₹)	Total Expenditure (₹)	Gross Return (₹)	Net Return (₹)	B:C Ratio
1	Coconut	31 nos.	505.03	3084.87	176.03	3765.93	7211.6	3445.67	1.91
2	Jack	2 nos.	-	487.49	-	487.49	1587.93	1100.44	3.26
3	Mango	2 nos.	5.68	814.17	44.01	863.86	1584.24	720.38	1.83
4	Gooseberry	1 no.	7.56	89.62	-	97.18	221.79	124.61	2.28
5	Tamarind	1 no.	-	184.38	17.6	201.98	620.69	418.71	3.07
6	Bread Fruit	1 no.	-	83.9	-	83.9	294.84	210.94	3.51
7	Cashew	1 no.	7.8	118.57	17.6	143.97	396.06	252.09	2.75
8	Arecanut	4 nos.		699.71		699.71	1346.61	646.9	1.92
9	Tapioca	142 nos.	1895.79	1918.69	272.84	4087.32	8863.83	4776.51	2.17
10	Banana	58 nos.	3296.45	5782.48	275.28	9354.21	18777.66	9423.45	2.01
11	Pepper	7 nos.	45.65	991.64	-	1037.29	3564.54	2527.26	3.44
12	Ginger	2 nos.	14.17	12.53	-	26.7	61.39	34.69	2.3
13	Turmeric	3 nos.	19.54	10.1	-	29.64	56.33	26.69	1.9
14	Curry Leaf	1 no.	-	18.57	-	18.57	54.08	35.52	2.91
15	Papaya	7 nos.	246.82	165.47	114.42	526.7	1135.37	608.67	2.16
16	Moringa	1 no.	-	28.16	-	28.16	65.13	36.97	2.31
17	Colocasia	6 nos.	46.25	41.97	-	88.22	184.83	96.61	2.1
18	Dioscorea	3 nos.	27.45	16.08	-	43.53	98.58	55.04	2.26
19	Amorphophallus	3 nos.	26.21	136.42	-	162.63	468.23	305.6	2.88
20	Annona	1 no.	6.86	215.74	-	222.6	484.07	261.48	2.17
21	Bilimbi	1 no.	-	24.09	-	24.09	68.65	44.56	2.85
22	Guava	1 no.	16.62	156.43	-	173.04	480.55	307.51	2.78
23	Pineapple	2 nos.	9.55	15.84	-	25.4	57.52	32.12	2.26
24	Vegetables	1 unit	324.65	1509.73	88.01	1922.39	4398.91	2476.52	2.29
25	Cattle	2 unit	57985.62	26380.57	112.08	84478.26	173506.6	89028.38	2.05
26	Goat	1 unit	5957.65	2084.81	-	8042.46	15600.54	7558.08	1.94
27	Poultry	10 unit	4508.96	1611.93	-	6120.89	13081.09	6960.2	2.14
Total			74954.3	46683.94	1117.87	122756.1	254271.7	131516	2.07

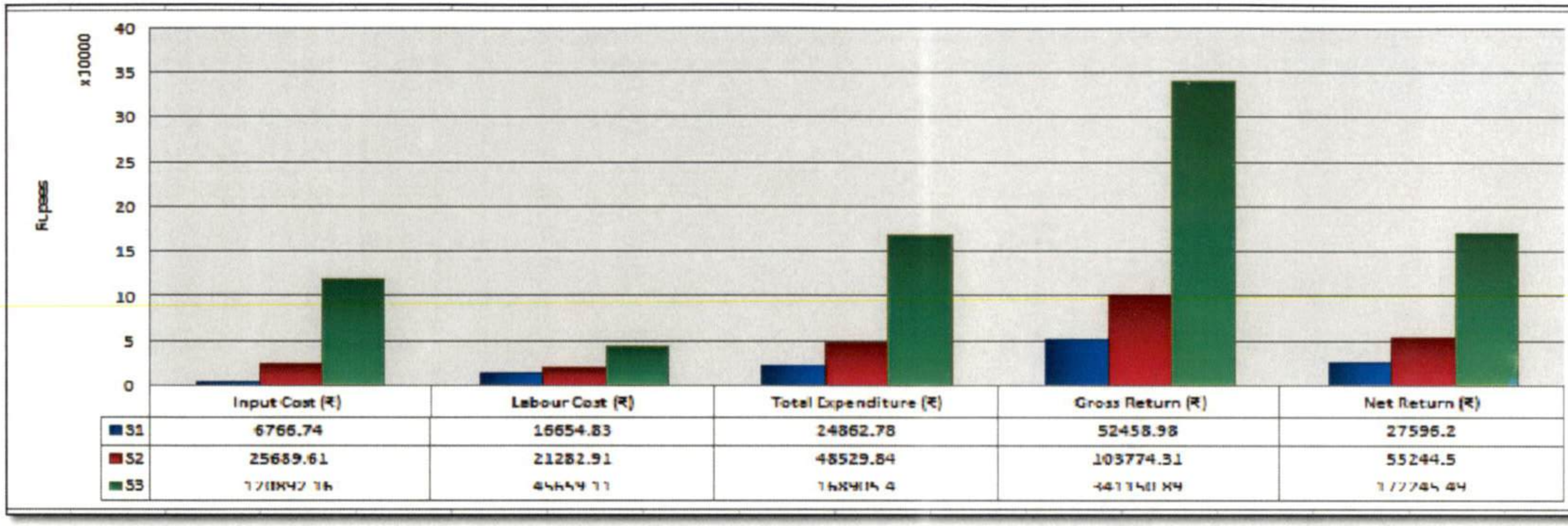


Fig. 20. Economic analysis of the homesteads at AEU 8

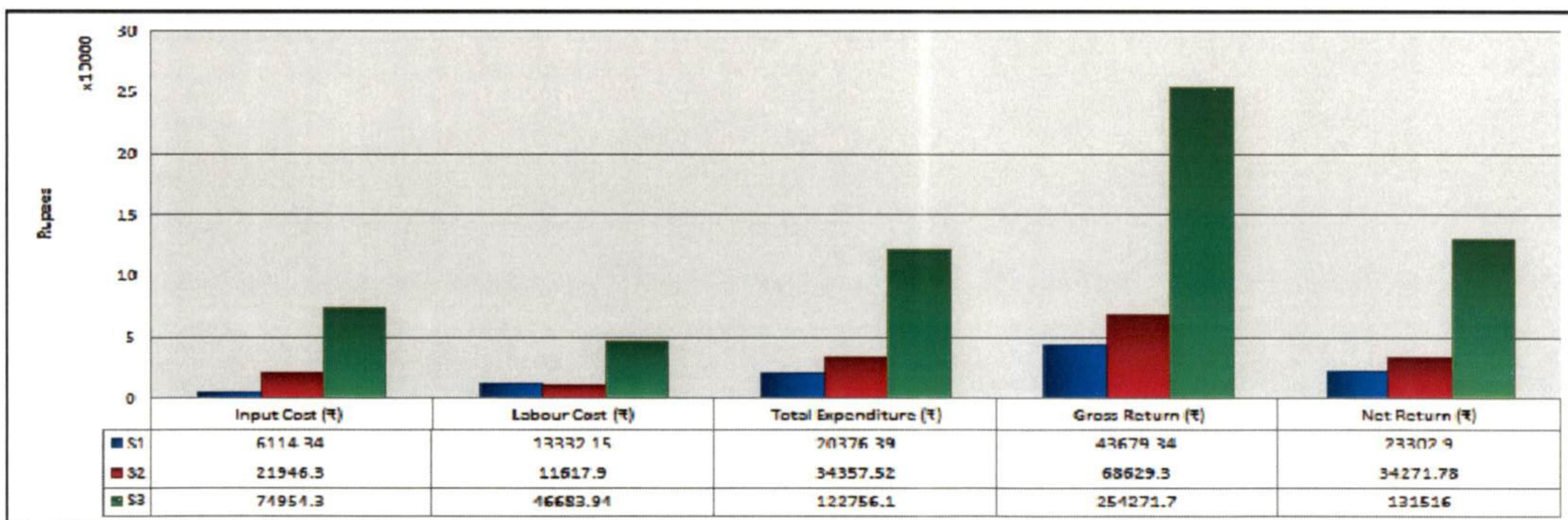


Fig. 21. Economic analysis of the homesteads at AEU 9

4.4 CROPPING/FARMING PATTERN UNDER DIFFERENT OPTIMUM HOMESTEADS MODELS.

4.4.1. Optimum Homestead Models in AEU 8

The optimum model for homesteads was developed by assuming the total expenditure incurred as investment amount for an average holding size of 45 cents in AEU 8. LP was used for developing the model and the optimum model consisted of house and permanent structures, crop and livestock enterprises with due importance to vegetables and coconuts on account of farmer's preferences. The model was developed with the objective of profit maximization subjected to number of constraints, expressed in the form of linear inequalities of using available resources. The linear objective function was developed by considering the entire enterprises in the objective function with unit net return of each enterprise serving as the coefficients. This was formulated separately for S_1(Appendix III), S_2(Appendix IV), and S_3(Appendix V), in AEU 8. All the enterprises were converted into linear constraints with right hand side value or available resources as the population of the enterprise with slight modification.

4.4.1.1 Optimum Model for S_1 Homestead Cropping System

In S_1, the population linear constraint of coconut according to the preference of farmers assumed a 15 which was obtained from the sampled homesteads with a maximum of 30 palms. All the enterprises in S_1 were also converted into linear constraints with RHS as populations given in Table 25. All the vegetables were grouped into a single unit from which two units were considered in the inequality constraint of vegetables. The optimum homestead model for S_1 is presented in Diagram 22. The optimum model of LP consisted of all enterprises with binding solution (*ie*, population in RHS of liner constraints) for almost all the enterprises except for the major enterprises, coconut and banana (Table 25). The benefit cost ratio obtained in the model was 2.2. The optimum model suggested a minimum number of 15 coconuts palms in the presence of other linear constraints. Moreover, in the optimal solution, crops such as banana, turmeric and colocasia were non-binding *ie*, it is not possible to increase the population up to the suggested limit, due to the limitation in available investment amount.

The optimum model developed for a homestead farmer in S_1 of AEU 8 by investing an amount of ₹ 28,793/- would receive a net profit of ₹ 34577/- (Table 25) which indicates 25.30 per cent enhancement in net profit over the existing plan (Fig 23). The optimum model left a total area of 439.79 m^2 with unutilized interspaced area of 390.27 m^2, which is an indication of laps in proper farm planning. Furthermore, the underutilized area may be effectively utilized by planting more crops by allowing sufficient area for house and permanent structures, which in turn may increase the cropping intensity as well as farm income. The functional diversity of the components may be selected by giving due importance to family preferences and interests to meet the livelihood of the farm household.

4.4.1.2. Optimum model for S_2 homestead farming system

`The optimum model for S_2 (S_{1+} goats + poultry) was also developed for an average homestead of size 45 cents with the linear objective function consisting of two additional variables in linear objective function of S_1, one for goat and one for poultry with per unit net return as coefficients. The functional diversity of the components included in the homesteads was preferably selected by the farmers, giving due importance to the family requirement, taste, interest and market demand for the enterprises. In $S_{2,}$ there were more inequality constraints related to goat and poultry. The linear inequality constraints of livestock/poultry components of the model in S_2 comprised a value of 2 to less than or equal to 4 for goats and 4 to 6 for poultry. According to Salam *et al.* (1992), LP solutions were mostly recommended for perennial crops due to high preference by farmers since their expenditure in terms of labor and input cost was less. In the present study also, all the perennial crops were observed with binding solution, subjected to all other constraints. The optimum model for average S_2 homesteads in AEU 8 comprising of 28 enterprises including house and permanent structures is presented in Fig 24. and Table 26.

Structure of Optimum LP model of S_1 in AEU 8 for an Area of 1800 m^2

Main area
Available - 1800 m^2
Used - 1060.21 m^2

Coconut -15
Jack - 2
Mango - 2
Gooseberry - 2
Tamarind - 2
Bread Fruit - 1
Cashew - 2
Arecanut - 3
House & Permanent Structures

Interspaces
Available - 677.44 m^2
Used - 390.27 m^2

Tapioca -108
Banana -47
Pepper -10
Ginger -8
Turmeric -7
Papaya -13
Moringa -2
Colocasia -5
Dioscorea -12
Amorphophallus -18
Sapota -1
Annona -1
Guava - 2
Vegetables -2

Investment amount
Available- ₹28820.03/-
Used - ₹28792.68/-

Gross return
₹63369.77/-

Net return
₹34577.09/-

Fig. 22. Optimization model for S_1 homesteads in AEU 8

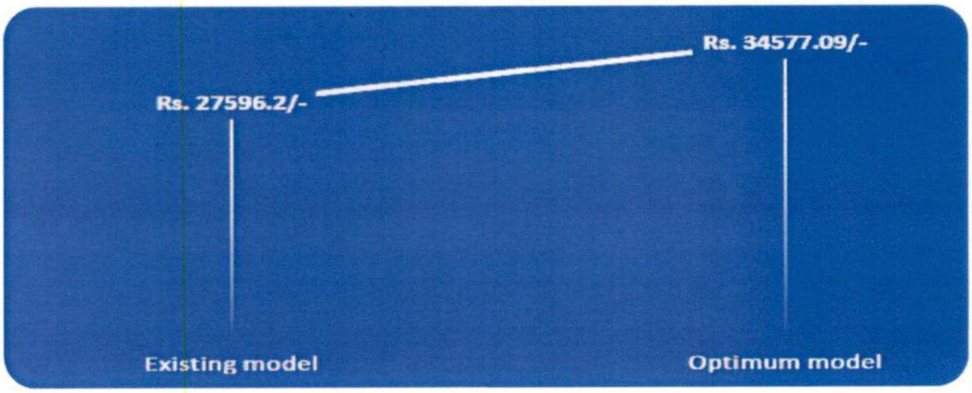


Fig. 23. Net income from existing and optimum model – S_1 AEU 8

Table 25. Optimum L P Homestead cropping model of S_1 in AEU 8

Sl.No	Enterprise	Value	Space(M^2)		Expendiure(₹)		Gross Return(₹)		Net Return (₹)	Constraints
			Unit	Total	Unit	Total	Unit	Total		
	Main Area									
1	Coconut	15 nos.	21.77	326.61	188.03	2820.51	330.23	4953.44	2132.93	15≥ ≤30
2	Jack	2 nos.	12.98	25.96	205.26	410.51	643.5	1287	876.49	≤2
3	Mango	2 nos.	4.03	8.07	301.01	602.01	707.67	1415.35	813.33	≤2
4	Gooseberry	2 nos.	18.24	36.47	175.59	351.19	616.04	1232.08	880.89	≤2
5	Tamarind	2 nos.	38.47	76.93	245.73	491.47	762.88	1525.76	1034.29	≤2
6	Bread Fruit	1 no.	67.89	67.89	144.3	144.3	383.96	383.96	239.66	≤1
7	Cashew	2 nos.	57.79	115.58	437.71	875.43	923.04	1846.08	970.65	≤2
8	Arecanut	3 nos.	8.04	24.12	128.63	385.88	410.84	1232.51	846.63	≤3
9	House & Permanent Structures	-	378.57	378.57	-	-	-	-	-	1
	Interspaces									
10	Tapioca	108nos.	0.87	93.47	32.08191	3464.85	67.69383	7310.93	3846.09	40≥≤108
11	Banana	47 nos.	2.4	112.99	181.7047	8540.12	372.18	17492.46	8952.34	≤60
12	Pepper	10 nos.	0.5	5.02	124.7867	1247.87	347.9375	3479.37	2231.51	≤10
13	Ginger	8 nos.	0.34	2.74	4.99886	39.99	12.22	97.76	57.77	≤7
14	Turmeric	7 nos.	0.92	6.41	9.245	64.72	15.35836	107.51	42.79	≤12
15	Papaya	13 nos.	2.01	26.12	65.02993	845.39	154.6806	2010.85	1165.46	≤13
17	Moringa	2 nos.	2.83	5.67	23.13063	46.26	59.93	119.86	73.6	1≥ ≤2
18	Colocasia	5 nos.	0.98	4.92	22.34	111.7	40.95563	204.78	93.08	5≥ ≤14
18	Dioscorea	12 nos.	0.64	7.63	27.7375	332.85	61.43345	737.2	404.35	≤12
19	Amorphophallus	18 nos.	1.06	19.01	32.673	588.11	94.06997	1693.26	1105.15	≤18
20	Sapota	1 no.	10.17	10.17	175.8228	175.82	318.686	318.69	142.86	≤1
21	Annona	1 no.	7.07	7.07	190.1623	190.16	445.3925	445.39	255.23	≤1
22	Guava	2 nos.	4.52	9.04	372.2715	744.54	930.7167	1861.43	1116.89	1≥ ≤2
23	Vegetables	2 unit	40	80	3159.503	6319.01	6807.056	13614.11	7295.11	≤2
	Interspace Total			390.27						≤677.44
	Main area Total			1060.21						≤1800.00
	Grand Total			1450.48		28792.68		63369.77	34577.09	

The livestock/poultry unit in the optimum model in S_2 comprised of 4 goats and 6 poultry (Table 26). In the optimum model, goat unit had a great role in rising the farm income by way of selling kids and poultry unit in most of the S_2 homesteads provided eggs and meat required for the farm family. The population constraint for coconut as per the preference of farmers was within a range of 18 to 30 palms. The optimum model suggested cultivation of minimum number of coconut palms keeping in, the view of other constraints, land requirement and investment amount. The optimal solution for coconut, colocasia, poultry and vegetables did not allow toincrease the population up to suggested limit, due to the constraint of scarce available investment capital. For all other enterprises, binding solution was obtained in the optimum model. The optimum model worked out for S_2 in AEU8 was found to have binding solution for almost all the enterprises except some enterprises like coconut, colocasia, poultry and vegetables with a B: C ratio of 1.95.

The optimum LP model developed by investing an amount of ₹63060.45/-by the S_2 homestead farmer would receive a net profit of ₹72535.78/- (Table 26) which indicates an enhancement of 31.30 per cent in net return as compared with the net return from the existing plan (Fig. 25). However, the available area in the homestead was underutilized by all enterprises including area for house and permanent structures in the optimum model with two vegetable units. It may be concluded that, there is a possibility of enhancing income further by increasing the population of enterprises which may or may not require additional capital investment. The possibility of incorporating all enterprises in the suggested or a greater limit by additional investment in capital will be discussed in the upcoming sections.

Structure of Optimum LP model of S_2 in AEU 8 for an Area of 1800 m^2

Main area
Available - 1800 m^2
Used - 1127.31 m^2

- Coconut -18
- Jack - 2
- Mango - 3
- Gooseberry - 2
- Tamarind - 2
- Bread Fruit - 2
- Cashew - 3
- Poultry - 6 unit
- Goat - 4 unit
- House & Permanent Structures

Interspaces
Available - 935.69 m^2
Used - 376.81 m^2

- Tapioca - 80
- Clove - 1
- Banana - 62
- Nutmeg - 1
- Pepper -18
- Ginger - 3
- Curry leaf - 1
- Papaya -20
- Moringa -2
- Colocasia -5
- Dioscorea -12
- Amorphophallus -10
- Sapota - 2
- Annona - 2
- Guava - 1
- Pineapple - 10
- Vegetables -2

Investment amount
Available- ₹63106.40/-
Used - ₹63060.45/-

Gross return
₹123214.7/-

Net return
₹72535.78/-

Fig. 24. Optimization model for S_2 homesteads in AEU 8

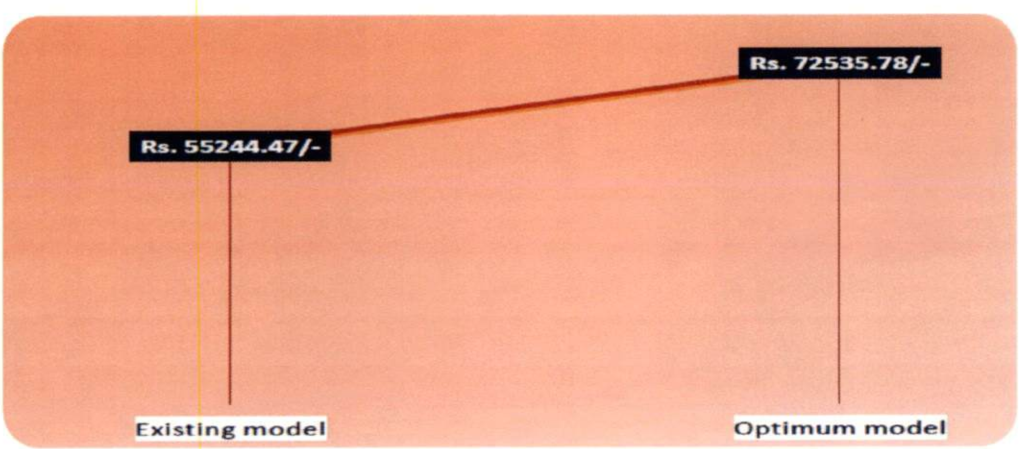


Fig. 25. Net income from existing and optimum model – S_2 AEU 8

Table 26. Optimum L P Homestead cropping model of S_2 in AEU 8

Sl.No	Enterprise	Value	Space(M^2)		Expendiure(Rs)		Gross Return(Rs)		Net Return (Rs)	Constraints
			Unit	Total	Unit	Total	Unit	Total		
	Main Area									
1	Coconut	18 nos.	12.25	220.46	189.2	3405.58	345.4599	6218.28	2812.7	18≥ ≤40
2	Jack	2 nos.	9.4	18.8	315.87	631.73	1151.15	2302.3	1670.57	1≥ ≤2
3	Mango	3 nos.	7.67	23	227.21	681.62	662.61	1987.83	1306.21	2≥ ≤3
4	Gooseberry	2 nos.	15.9	31.79	202.36	404.72	448.5342	897.07	492.35	1≥ ≤2
5	Tamarind	2 nos.	20.42	40.84	298.54	597.07	881.65	1763.3	1166.23	1≥ ≤2
6	Bread Fruit	2 nos.	15.31	30.61	166.32	332.64	420.33	840.66	508.02	1≥ ≤3
7	Cashew	3 nos.	50.24	7	390.66	1171.99	753.42	2260.26	1088.27	1≥ ≤2
8	Goat	4 nos.	7	3	5497.02	21988.07	13248.51	52994.05	31005.99	2≥ ≤4
9	Poultry	6 nos.	3	3	1425	8550	2290.17	13741.01	5191.01	6≥ ≤15
10	House & Permanent Structures	1	372	372	-	-	-		-	1
	Interspaces									
11	Tapioca	80 nos.	1.2	95.78	32.9	2632.14	67.47928	5398.34	2766.2	60≥ ≤80
12	Clove	1 no.	3.33	3.33	249.99	249.99	762.215	762.21	512.22	≤1
13	Banana	62 nos.	1.72	106.61	167.39	10377.94	327.939	20332.22	9954.27	15≥ ≤62
14	Nutmeg	1 no.	11.82	11.82	379.95	379.95	879.4788	879.48	499.53	≤1
15	Pepper	18 nos.	0.38	6.92	120.15	2162.75	320.3867	5766.96	3604.21	≤18
16	Ginger	3 nos.	0.31	0.93	7.4	22.21	14.565	43.7	21.49	≤3
17	Curry Leaf	1 no.	1.41	1.41	19.72	19.72	71.25	71.25	51.53	≤1
18	Papaya	20 nos.	1.77	35.33	80.35	1606.96	184.2718	3685.44	2078.47	2≥ ≤20
19	Moringa	2 nos.	1.77	3.53	61.82	123.64	131.61	263.22	139.58	≤2
20	Colocasia	5 nos.	0.58	2.9	37.6	188.01	54.96743	274.84	86.82	5≥ ≤12
21	Dioscorea	12nos.	0.64	7.63	30.32	363.8	56.67752	680.13	316.33	8≥ ≤12
22	Amorphophallus	10 nos.	0.48	4.78	62.93	629.27	205.2117	2052.12	1422.85	2≥ ≤10
23	Sapota	2 nos.	6.6	13.2	204.08	408.16	406.759	813.52	405.36	1≥ ≤2
24	Annona	2 nos.	7.07	14.13	262.11	524.22	513.0293	1026.06	501.84	1≥ ≤2
25	Bilimbi	2 nos.	1.72	3.44	37.22	74.44	107.7362	215.47	141.03	≤2
26	Guava	1 no.	8.04	8.04	250.61	250.61	521.0912	521.09	270.48	≤1
27	Pineapple	10 nos.	0.5	5.02	13.39333	133.93	29.43	294.3	160.37	≤10
28	Vegetables	2 unit	26	52	2576.634	5153.27	4757.57	9515.14	4361.87	1≥ ≤3
	Interspace total			376.81						≤935.69
	Total main area			750.5						≤1800.00
	Grand total			1127.31		63064.45		123214.7	72535.78	

4.4.1.3. Optimum Model for S_3 Homestead Farming System

In S_3 homestead, a minimum of 15 adult bearing coconut palms was required for the farm family but the solution of LP problem with the objective of maximization of farm income was found feasible without incorporating more coconut palm, subjected to unit net income and other constraints for coconut palm, failed to give a best feasible solution. However, in view of socially acceptable nature of homesteads, LP problem formulated a solution *viz*; investment amount and area needed for 15 coconut palms was subtracted from total available number of palms and LP problem was solved with resources kept for rest of the enterprises. Crops like banana, sapota, turmeric and poultry did not reach the suggested limit, even though the land area was abundant, because of the constraint, lack of capital for investing on the homesteads. For all other enterprises, optimum model had binding solution. The prospect of further enhancing the income by incorporating all enterprises in the suggested limit with an additional capital investment is discussed in the upcoming sections.

The practical difficulty in variety of the components preferentially opted by the farmers, gives much significance to the family requirement, taste, interest and market demand of the enterprises. The livestock/poultry components of the model comprised of 3 cattle, 4 goats and 10 poultry (Fig. 26). The livestock integration with crops was found to provide a high degree of organic recycling between the systems, which further helps to maintain soil health and sustainable productivity.

The optimum model for S_3 homestead in AEU 8 was developed by investing an amount of ₹188331.05/-. The farmer would obtain a net profit of ₹195182.96/- (Table 27) which shows an enhancement of 13.31 per cent in net return as compared to the net return from the existing plan (Fig 27). The optimum model worked out for S_3 in AEU 8 was being found with binding solution for almost all the enterprises except some enterprises like banana, poultry and turmeric with B: C ratio of 2.04.

Structure of Optimum LP model of S_3 in AEU 8 for an Area of 1800 m^2

Main area
Available - 1800 m^2
Used - 988.9 m^2

Coconut -15
Jack - 1
Mango - 3
Gooseberry - 2
Tamarind - 1
Bread Fruit - 2
Cashew - 2
Poultry - 10 unit
Goat - 4 unit
Cattle - 3 unit
House & Permanent Structures

Interspaces
Available - 935.69 m^2
Used - 376.81 m^2

Tapioca - 80
Banana - 21
Pepper -8
Ginger - 8
Turmeric - 8
Curry leaf - 2
Papaya - 10
Moringa - 1
Colocasia -12
Dioscorea - 9
Amorphophallus - 7
Annona - 1
Guava - 1
Vegetables -2 unit

Investment amount
Available- ₹188248.4/-
Used - ₹188331.05/-

Gross return
₹383514.01/-

Net return
₹195182.96/-

Fig. 26. Optimization model for S_3 homesteads in AEU 8

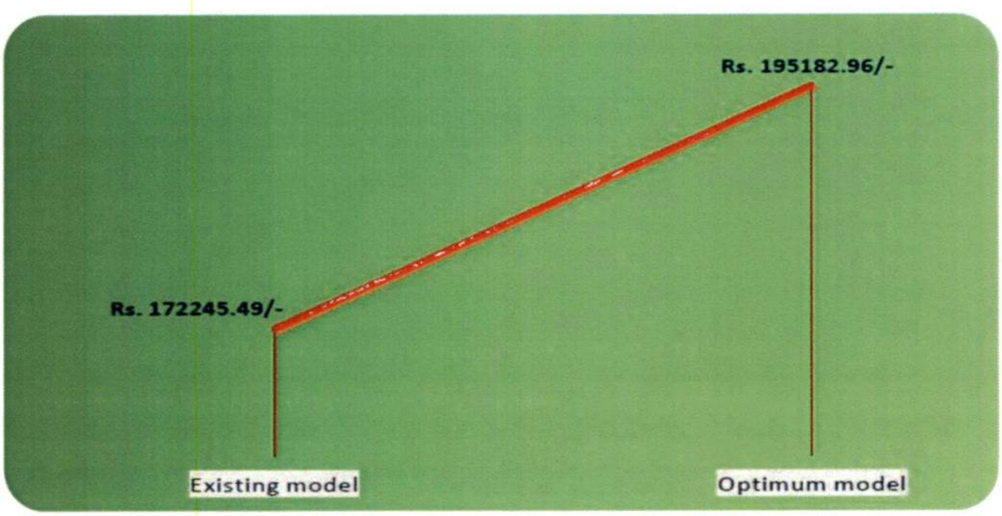


Fig. 27. Net income from existing and optimum model – S_3 AEU 8

Table 27. Optimum L P Homestead cropping model of S_3 in AEU 8

Sl. No	Enterprise	Value	Space(M2		Expendiure(Rs)		Gross Return(Rs)		Net Return (Rs)	Constraints
			Unit	Total	Unit	Total	Unit	Total		
Main Area										
1	Coconut	15 nos.	8.04	120.58	170.2549	2553.82	332.749	4991.24	2437.41	15≥ ≤35
2	Jack	1 no.	4.67	4.67	352.563	352.56	1075.38	1075.38	722.82	1≥ ≤2
3	Mango	3 nos.	5.89	17.68	279.3256	837.98	695.1759	2085.53	1247.55	≤3
4	Gooseberry	2 nos.	3.14	6.28	102.91	205.82	388.9447	777.89	572.07	≤2
5	Tamarind	1 no.	11.04	11.04	128.1407	128.14	509.5477	509.55	381.41	≤1
6	Bread Fruit	2 nos.	21.23	42.45	191.2184	382.44	481.21	962.42	579.98	≤2
7	Cashew	2 nos.	30.18	60.35	320.3518	640.7	643.7186	1287.44	646.73	≤3
8	Cow	3 nos.	12	12	41151.97	123455.91	81800	245400	121944.09	≤3
9	Goat	4 nos.	5	5	8047.34	32189.36	17000	68000	35810.64	≤4
10	Poultry	10 nos.	3.5	3.5	994.0961	9940.96	1881.367	18813.67	8872.71	≤15
11	House & Permanent Structures	1	438.69	438.69	0	0	-	0		1
Interspaces										
12	Tapioca	80 nos.	0.58059	46.45	33.86	2708.94	74.044	5923.52	3214.58	≤80
13	Banana	21 nos.	2.5434	53.41	171.73	3606.33	338.1523	7101.2	3494.87	20≥≤45
14	Pepper	8 nos.	0.5024	4.02	173.37	1386.99	439.1967	3513.57	2126.58	2≤8
15	Ginger	8 nos.	0.66442	5.32	3.4	27.19	9.723618	77.79	50.6	≤8
16	Turmeric	8 nos.	0.72346	5.79	6.59	52.7	11.39698	91.18	38.47	≤10
17	Curry Leaf	2 nos.	1.02019	2.04	32.91	65.81	89.4	178.8	112.99	≤2
18	Papaya	10 nos.	1.62778	16.28	68.77	687.68	174.8744	1748.74	1061.06	≤10
19	Moringa	1 no.	4.5216	4.52	17.88	17.88	77.45	77.45	59.57	≤1
20	Colocasia	12 nos.	0.88203	10.58	16.76	201.15	33.9196	407.04	205.89	≤12
21	Dioscorea	9 nos.	0.63585	5.72	29.39	264.53	67.8392	610.55	346.02	≤9
22	Amorphophallus	7 nos.	0.75391	5.28	47.26	330.81	131.9095	923.37	592.55	≤7
24	Annona	1 no.	3.20311	3.2	291.59	291.59	731.1558	731.16	439.57	≤1
25	Bilimbi	1 no.	1.32665	1.33	37.74	37.74	86.16	86.16	48.42	≤1
26	Guava	1 no.	9.72646	9.73	260.5037	260.5	678.39	678.39	417.89	≤1
27	Vegetables	2 unit	46.5	93	3851.754	7703.51	8730.99	17461.99	9758.48	≤2
	Interspace total			266.66						≤1043.61
	Main area total			722.24						≤1800.00
	Grand total			988.9		188331.05		383514.01	195182.96	

4.4.2 Optimum Model for AEU 9 Homesteads Cropping/ Farming Systems

The optimum model for homesteads was developed using LP, by assuming the total expenditure incurred as investment amount for an average holding size of 52.5 cents (2100 m^2) in AEU 9. The linear objective function was developed by considering the entire enterprises in the objective function with unit net return of each enterprise serving as the coefficients. This was formulated separately for S_1 (Appendix VI), S_2 (Appendix VII), and S_3 (Appendix VIII), in AEU 9.

4.4.2.1. Optimum Model for S_1 Homestead Cropping System

In S_1 homestead, the population linear constraint for coconut according to the preference of farmers was in the range of 14 to 30 palms. The optimum model suggested that growing minimum number of coconuts would be the best, subjected to the present constraints. The optimal solution obtained was non-binding for enterprises like coconut, cashew, ginger, dioscorea, pineapple and banana but binding solution for all other enterprises. *i.e.*, it is not possible to increase the population up to suggested limit, due to the constraint of limited initial investment available. For all other enterprise, binding solution was obtained in the optimum model.

The optimum model for S_1 developed by investing an amount of ₹ 23384.18/- would receive a net profit of ₹ 28623.72/- (Table 28) indicating 22.83 per cent enhancement in net return as compared to net return from the existing plan, with B: C ratio of 2.22 (Fig.29). Prime importance was given to the family requirement, taste, interest and market demand for the enterprises while selecting the diverse components by the framers.

For further increase of income from homesteads, the land area available as uncultivated and occupied by uneconomical enterprises must be utilized in economical manner but the LP showed that investment amount available was not enough to meet these expenses, hence farmers may give more emphasis on growing diverse crops by investing more to ensure food security.

The optimum model for average S_1 homesteads in AEU 8, comprising of 23 enterprises including house and permanent structures is presented in Fig.28 and Table 28.

4.4.2.2. Optimum Model for S_2 Homestead Cropping System

In S_2, the population constraint of coconut according to the preference of farmers was noticed ranging from 18 to 26 palms. Considering the constraints, the optimum model with the objective of maximization of farm income was found feasible with the incorporation of minimum number of coconut palms. The optimal solution for the enterprises was not binding *ie*. It is not possible to increase the population up to the suggested limit, due to the scarce availability of investment amount. Binding solution was obtained for all other enterprise, in the model.

The optimum model designed for a homestead farmer in S_2 of AEU 9 by investing an amount of ₹53616/- would receive a net profit of ₹56475.57/- (Table 29) which showed an enhancement of 64.79 per cent in net return as compared to that from the existing plan (Fig 31). In the model, non binding solution was obtained for enterprises like coconut, mango, banana, papaya, dioscorea, guava and poultry and binding solution for rest of the enterprises, with B: C ratio of 2.05.

As in case of S_1, the functional diversity of the components of homestead shall be selected giving significance to family preferences and interests in addition to market demand of the enterprises. Model consisted of livestock/poultry component with 4 goats and 14 poultry. In the optimum model, goat unit was noticed efficient in enhancing farm income by way of selling kids. Poultry unit was found as a basic requirement in most of the S_2 homesteads to meet the demand for meat and egg for the farm family.

Structure of Optimum LP model of S_1 in AEU 9 for an Area of 2100 m^2

Main area
Available - 2100 m^2
Used - 1176.25 m^2

Coconut -18
Jack - 2
Mango - 3
Gooseberry - 2
Tamarind - 1
Bread Fruit - 2
Cashew - 1
House & Permanent Structures

Interspaces
Available - 935.69 m^2
Used - 368.34 m^2

Tapioca - 140
Banana - 47
Pepper -16
Ginger -
Turmeric - 10
Papaya -20
Colocasia - 10
Dioscorea - 6
Amorphophallus -15
Sapota - 3
Bilimbi - 2
Annona - 2
Guava - 2
Pineapple - 7
Vegetables -2

Investment amount
Available- ₹23,384 .18/-
Used - ₹23384.18/-

Gross return
₹52007.9/-

Net return
₹28623.72/-

Fig. 28. Optimization model for S_1 homesteads in AEU 9

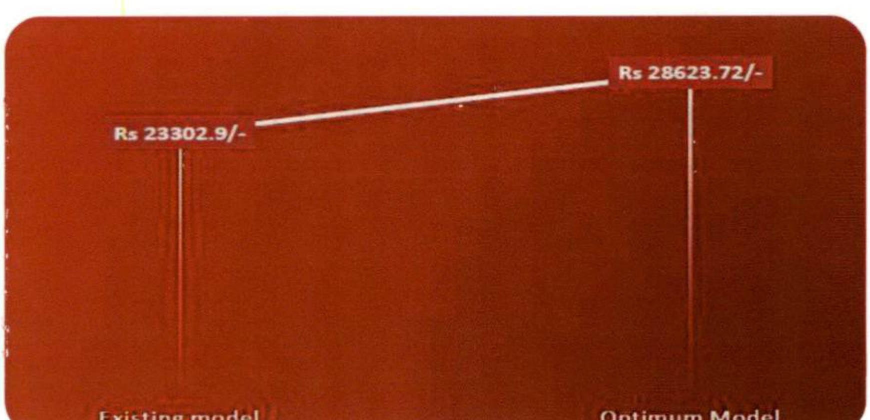


Fig. 29. Net income from existing and optimum model – S_1 AEU 9

Table 28. Optimum L P Homestead cropping model of S_1 in AEU 9

Sl.No	Enterprise	Value	Space(M2)		Expendiure(Rs)		Gross Return(Rs)		Net Return (Rs)	Constraints
			Unit	Total	Unit	Total	Unit	Total		
Main Area										
1	Coconut	14 nos.	15.2	212.77	124.68	1745.49	229.46	3212.38	1466.89	14≥≤30
2	Jack	2 nos.	6.15	12.31	223.22	446.43	792.68	1585.35	1138.92	≤2
3	Mango	3 nos.	6.6	19.81	276.11	828.33	838.92	2516.76	1688.43	≤3
4	Gooseberry	2 nos.	7.07	14.13	110.32	220.63	346.71	693.42	472.79	≤2
5	Tamarind	1 no.	36.3	36.3	190.19	190.19	634.02	634.02	443.83	≤1
6	Bread Fruit	2 nos.	19.63	39.25	108.02	216.03	367.99	735.98	519.95	≤2
7	Cashew	1 no	78.5	78.5	216.63	216.63	405.61	405.61	188.98	1≥≤3
8	House & Permanent Structures	1	394.86	394.86	-	-	-	-	-	1
Interspaces										
10	Tapioca	100nos.	0.79	78.5	27.4128	2741.28	65.66623	6566.62	3825.34	≤100
11	Banana	47 nos.	1.13	53.13	168.545	7921.63	336.7198	15825.83	7904.2	35≥≤55
12	Pepper	16 nos.	0.38	6.15	119.098	1905.56	345.325	5525.2	3619.64	≤16
13	Ginger	7 nos.	0.32	2.25	10.1944	71.36	19.45093	136.16	64.8	7≥≤10
14	Turmeric	10 nos.	0.64	6.36	3.94081	39.41	10.28037	102.8	63.4	5≥≤10
15	Papaya	20 nos.	1.91	38.21	61.2598	1225.2	138.3567	2767.13	1541.94	≤20
17	Colocasia	10 nos.	2.01	20.1	16.21	162.1	25.54517	255.45	93.35	10≥≤12
18	Dioscorea	6 nos.	1.45	8.71	12.8747	77.25	21.80685	130.84	53.59	6≥≤10
18	Amorphophallus	15 nos.	1.77	26.49	29.7313	445.97	85.86449	1287.97	842	≤15
19	Sapota	3 nos.	7.07	21.2	184.727	554.18	414.42	1243.26	689.08	1≥≤3
20	Bilimbi	2 nos.	2.83	5.67	40.65	81.3	95.7	191.4	110.1	1≥≤2
21	Guava	2 nos.	8.04	16.08	163.182	326.36	414.9533	829.91	503.54	≤2
22	Pineapple	7 nos.	0.79	5.5	18.7022	130.92	35.04673	245.33	114.41	7≥≤13
23	Vegetables	2 unit	40	80	1918.97	3837.94	3558.24	7116.48	3278.54	2
	Interspace total			368.34						≤1091.65
	Total main area			807.92						≤2100.00
	Grand total			1176.25		23384.18		52007.9	**28623.72**	

The future prospects of increasing income by incorporating all enterprises in suggested by way of adding capital investment is discussed in the upcoming sections.

The optimum model for average S_2 homesteads in AEU 9 comprising of 18 enterprises including house and permanent structures is presented in Fig 31. and Table 28.

4.5.2.3. Optimum Model for S_3 Homestead Cropping System

In S_3 homestead, optimum model was developed considering population of enterprises as linear constraint where a minimum of 20 adult bearing coconut palms was required for the farm family with an upper limit of 30. As per the optimum model, minimum number of coconut palms was recommended, considering several production constraints. Population of coconut and mango did not reach the suggested limit, even though the land area was abundant, which was due to the scarce investment income available. For all other enterprise, binding solution was obtained in the optimum model.

The livestock/poultry component of the model consisted of 3 cattle, 2 goats and 10 poultry. Integration of livestock with crops was observed to provide a high degree of organic recycling between the systems which could bring about enhancement and maintenance of soil health and sustainable productivity. Due importance was given to several factors such as family preferences, interests and tastes by the farmers while selecting diverse components for the farming system.

The optimum model developed for homestead farmer in S_3 of AEU 9 by investing an amount of ₹188331.05/- would receive a net profit of ₹190614.22/- (Table 30) indicating 44.94 per cent increase in net return over the existing plan (Fig.33). The optimum model developed for S_3 in AEU 9 obtained binding solution for almost all the enterprises except coconut and mango with B:C ratio of 2.09.

Structure of Optimum LP model of S_2 in AEU 9 for an Area of 2100 m^2

Main area
Available - 2100 m^2
Used - 1409.19 m^2

Interspaces
Available - 1281.51m^2
Used - 432.85 m^2

Investment amount
Available- ₹53,616/-
Used - ₹53616/-

Coconut -18
Jack - 3
Mango - 2
Gooseberry - 2
Cashew - 2
Goat - 4
poultry - 14
House & Permanent Structures

Tapioca -80
Banana -45
Pepper -20
Curry leaf -6
Turmeric -7
Papaya - 6
Colocasia -18
Dioscorea -6
Amorphophallus -15
Bilimbi -1
Annona -1
Guava - 1
Vegetables -4 unit

Gross return
₹110092/-

Net return
₹56475.57/-

Fig. 30. Optimization model for S_2 homesteads in AEU 9

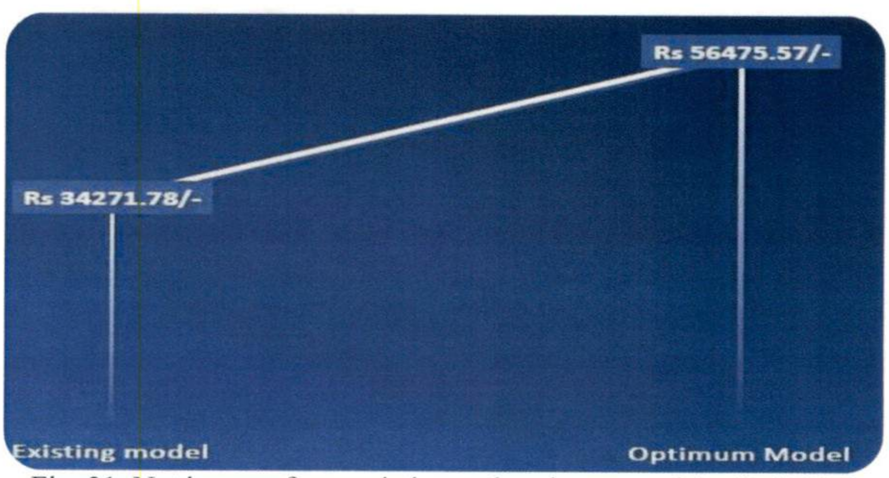


Fig. 31. Net income from existing and optimum model – S_2 AEU 9

Table 29. Optimum L P Homestead cropping model of S_2 in AEU 9

Sl.No	Enterprise	Value	Space(M)		Expenditure(Rs)		Gross Return(Rs)		Net Return (Rs)	Constraints
			Unit	Total	Unit	Total	Unit	Total		
	Main Area									
1	Coconut	18 nos.	15.9	286.13	121.25	2182.55	220.362	3966.52	1783.97	18≥≤26
2	Jack	3 nos.	8.04	24.12	48.69	146.07	169.625	508.88	362.81	≤3
3	Mango	2 nos.	7.07	14.13	431.64	863.28	769.165	1538.33	675.05	2≥ ≤3
4	Cashew	2 nos.	105.63	211.26	148.34	296.68	296.683	593.37	296.68	≤3
5	Goat	4 nos.	6	3	5758.89	23035.6	12004.2	48016.6	24981.05	≤4
6	Poultry	14 nos.	3.5	3	698.33	9776.6	1393.21	19504.9	9728.27	≤15
7	Home	1	434.71	434.71	-	-	-		-	1
Interspaces										
8	Tapioca	80 nos.	1.54	123.09	30.16	2412.87	61.8503	4948.02	2535.15	≤80
9	Banana	45 nos.	2.01	90.43	159.74	7188.4	309.582	13931.2	6742.8	45≥≤55
10	Pepper	20 nos.	0.5	10.05	74.84	1496.8	232.187	4643.73	3146.93	≤20
11	Turmeric	6 nos.	0.79	4.71	5.42	32.51	15.4791	92.87	60.37	≤6
11	Curry Leaf	2 nos.	0.64	1.27	15.29	30.58	45.1456	90.29	59.71	≤2
12	Papaya	6 nos.	1.91	11.46	68.8	412.78	132.217	793.3	380.53	6≥≤14
13	Colocasia	18 nos.	2.27	40.84	17.09	307.65	36.5479	657.86	350.21	≤18
14	Dioscorea	6 nos.	1.54	9.23	27.37	164.22	41.2776	247.67	83.45	6≥≤8
14	Amorphophallus	15 nos.	1.77	26.49	79.01	1185.12	158.016	2370.24	1185.12	≤15
15	Annona	1 no.	20.58	20.58	100.91	100.91	270.885	270.88	169.98	≤1
16	Bilimbi	1 no.	4.52	4.52	18.81	18.81	48.3722	48.37	29.56	≤1
17	Guava	1 no.	10.17	10.17	131.25	131.25	255.405	255.41	124.16	1≥≤2
18	Vegetables	4 unit	20	80	958.35	3833.4	1903.29	7613.16	3779.76	≤4
	Interspace total			432.85						≤1281.51
	Main area total			976.35						≤2100.00
	Grand total			1409.19		53616		110092	56475.57	

Structure of Optimum LP model of S_3 in AEU 9 for an Area of 2100 m^2

Main area
Available - 2100 m^2
Used -1250.4 m^2

Coconut -20
Jack - 2
Mango - 1
Gooseberry - 2
Tamarind - 1
Bread Fruit - 1
Cashew - 1
Poultry - 10
Goat - 2
Cattle - 3
House & Permanent Structures

Interspaces
Available 1109.64 m^2
Used - 434.4 m^2

Tapioca - 85
Banana - 65
Pepper -20
Ginger - 4
Turmeric - 8
Curry leaf - 1
Papaya - 8
Moringa - 2
Colocasia -17
Dioscorea - 15
Amorphophallus - 20
Annona - 1
Bilmbi -2
Guava - 2
Pineappl - 10
Vegetables -2 unit

Investment amount
Available- ₹1,76,958 /-
Used - ₹ 175660.62/-

Gross return
₹366274.84/-

Net return
₹190614.22/-

Fig. 32. Optimization model for S_3 homesteads in AEU 9

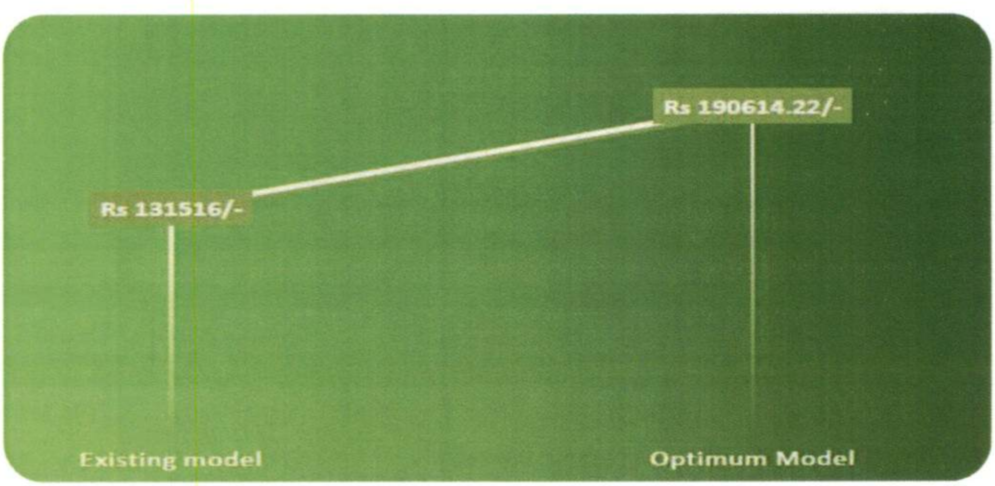


Fig. 33. Net income from existing and optimum model – S_3 AEU 9

Table 30. Optimum L P Homestead cropping model of S_3 in AEU 9

Sl.No	Enterprise	Value	Space(M^2)		Expendiure(Rs)		Gross Return(Rs)		Net Return (Rs)	Constraints
			Unit	Total	Unit	Total	Unit	Total		
Main Area										
1	Coconut	20 nos.	10.75	214.93	121.482	2429.63	232.6322	4652.64	2223.01	20≥≤30
2	Jack	2 nos.	6.15	12.31	243.745	487.49	793.9625	1587.93	1100.44	1≥ ≤2
3	Mango	1 no.	32.15	32.15	431.928	431.93	792.1207	792.12	360.19	≤2
4	Gooseberry	2 nos.	6.15	12.31	97.182	194.36	221.7938	443.59	249.22	≤2
5	Tamarind	1 no.	13.85	13.85	201.983	201.98	620.69	620.69	418.71	≤1
6	Bread Fruit	1 no.	16.61	16.61	83.9	83.9	294.8449	294.84	210.94	≤1
7	Cashew	1 no.	50.24	50.24	143.968	143.97	396.0604	396.06	252.09	1
8	Cow	3 nos.	12	12	42239.1	126717.4	86753.32	260259.96	133542.56	≤3
9	Goat	2 nos.	5	5	8042.46	16084.92	15600.54	31201.08	15116.16	≤4
10	Poultry	10 nos.	3	3	612.089	6120.89	1308.109	13081.09	6960.2	≤15
11	Home	1 no.	443.59	443.59	-	-	-	-	-	1
Interspaces										
12	Tapioca	85 nos.	0.785	66.73	28.7839	2446.63	62.42134	5305.81	2859.18	≤85
13	Banana	65 nos.	2.3223	150.95	161.279	10483.17	323.7528	21043.93	10560.76	≤65
14	Pepper	20 nos.	0.4534	9.07	148.184	2963.67	509.2205	10184.41	7220.74	≤20
15	Ginger	4 nos.	0.5024	2.01	13.3483	53.39	30.69468	122.78	69.39	≤4
16	Curry Leaf	1 no.	2.0096	2.01	18.565	18.57	54.08	54.08	35.52	≤1
18	Papaya	8 nos.	1.7663	14.13	75.2432	601.95	162.1961	1297.57	695.62	≤8
19	Moringa	2 nos.	5.3066	10.61	28.16	56.32	65.12992	130.26	73.94	≤2
20	Colocasia	17 nos.	2.0096	34.16	14.7033	249.96	30.80469	523.68	273.72	≤17
21	Dioscorea	15 nos.	1.1304	16.96	14.5114	217.67	32.85834	492.88	275.2	≤15
22	Amorphophallus	20 nos.	0.785	15.7	54.2103	1084.21	156.0771	3121.54	2037.34	≤20
23	Annona	1 no.	4.5216	4.52	222.597	222.6	484.0738	484.07	261.48	≤1
24	Bilimbi	2 nos.	1.5386	3.08	24.0855	48.17	68.65046	137.3	89.13	≤2
25	Guava	2 nos.	9.7265	19.45	173.044	346.09	480.5532	961.11	615.02	≤2
26	Pineapple	10 nos.	0.5024	5.02	12.6982	126.98	28.76	287.6	160.62	≤10
27	Vegetables	2 unit	40	80	1922.39	3844.78	4398.91	8797.82	4953.04	≤2
	Interspace total			434.4						≤1109.644
	Main area total			815.99						≤2100.00
	Grand total			1250.4		175660.62		366274.84	190614.22	

4.5 COMPARISON OF OPTIMUM HOMESTEAD MODELS UNDER DIFFERENT CROPPING AND FARMING SYSTEMS

The main objective of the study was to explore the possibilities of augmenting income of farmers from the various activities in the homesteads. The LP problem formulated in this view and the optimum model developed through iterative procedure would give maximum return, subjected to constraints *viz.* total area available, inter cropping area available, investment amount and population constraints.

As per evidenced from both AEU's, the drastic change in farm income between different cropping/farming systems is attributed to the livestock/poultry enterprises and hence the incorporation of the livestock/poultry enterprises in the homesteads which could contribute a major share of farm income is recommended.

It is observed that, S_1 homesteads can easily incorporate goat and poultry and from the figure it is clear that in both AEU's, the net income in S_2 is almost twice that of S_1 (Fig 34). Addition of cattle unit in the homesteads is found to enhance the farm income. It can be suggested that, the incorporation of cattle unit in S_2 homesteads can make homesteads more fruitful if the farmer is willing to invest more in the homestead and family labour itself is ready to take care of the cattle unit. The net income of S_3 farmer is close to thrice that of S_2 in AEU 8 and more than thrice in AEU 9. This result is in line with the research on additional farm income by cattle in the mixed system by Pandey and Bhogal (1980) and Subhadra (2007).

`It was also found that even if income from livestock was high, farmers preferred to have the intercrops and allied enterprises which need less management practices and labour. The same inferencs were reported by Helen and Smitha (2013) about the homestead farmers of Palakkad district of Kerala.

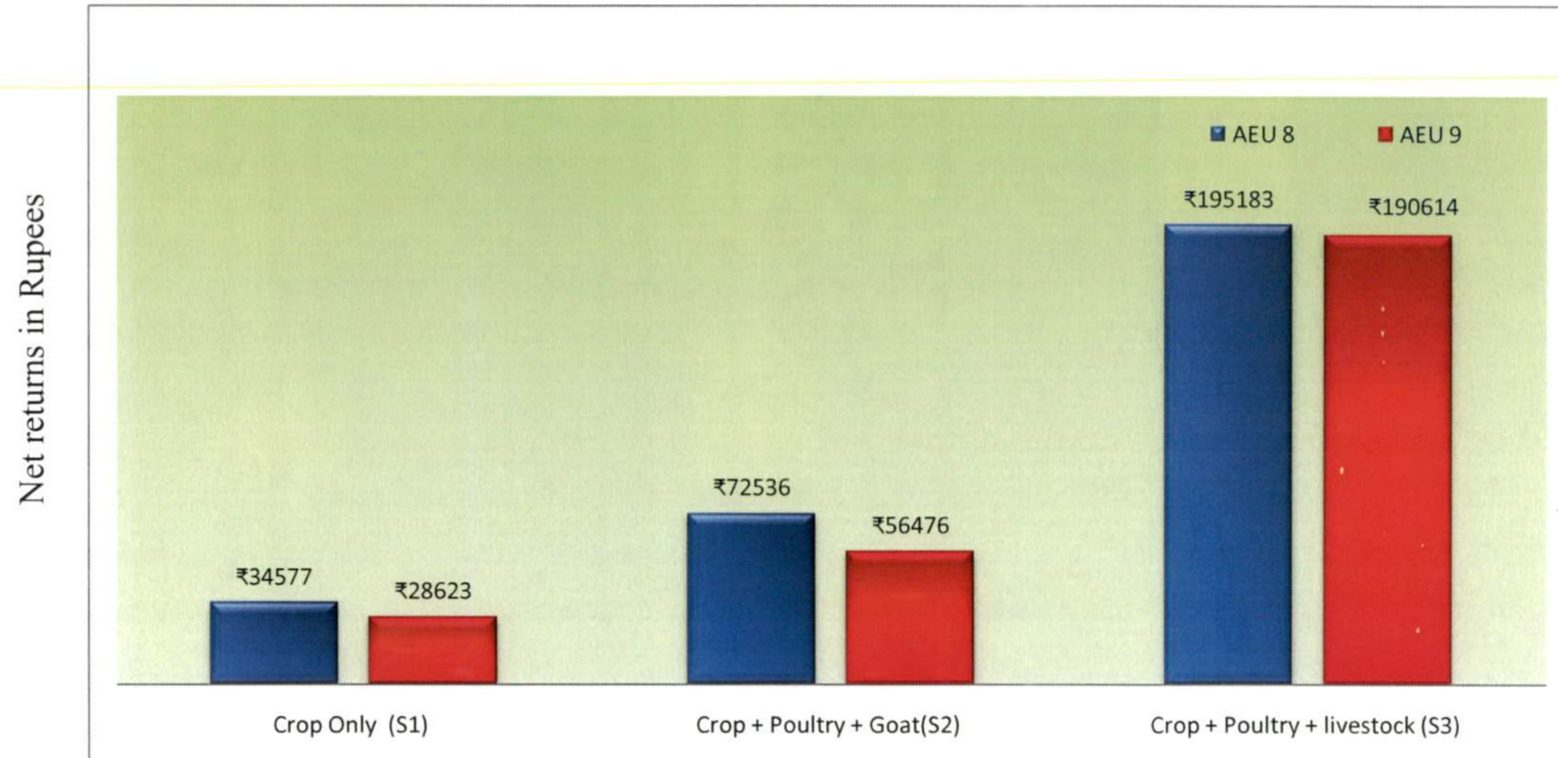


Fig. 34. Net return in the optimum model of S_1, S_2 and S_3 in both AEU's

4.6 SENSITIVITY ANALYSIS OF DIFFERENT OPTIMUM MODELS.

Sensitivity analysis gives insight on how the optimal solution changes when we change the coefficients of the model. It gives information about optimal solution for changes in the objective function coefficient for variables and for the changes in the right-hand side (RHS) of constraints or available resources. More specifically, sensitivity analysis is done to explore the net return obtained with respect to change in and available resources/population constraints value.

4.6.1. Sensitivity Analysis of S_1 in AEU 8

Sensitivity analysis of the S_1 model of AEU 8 presented in Table 31, exposed minimum and maximum range of net income for each enterprise, where the optimal LP solution will remain unchanged within these range of values of the enterprises. Moreover, Table 32 provides the change in objective function coefficient for binding and non binding enterprise so that the feasibility of the LP model remains valid. It is more consequential to look for maximum change of objective coefficient/ unit net return of the enterprises having non binding solution and minimum range for enterprises with binding solutions to check the credibility of model. The value of coconut in the optimal plan was fifteen when the unit net return of coconut palm was ₹142.2/- and the model remains stable until the unit net income reaches ₹197.12/-. Similarly for banana and turmeric, the maximum range allowable increase in unit net return was ₹201.47/- and ₹9.69/- respectively. However, in the case of binding enterprises, the optimal LP model will be same until the net return reduces to certain limit as specified in Table 30. For example, in the case the binding enterprises jack and mango, the optimum model will be same until the unit net return reduces to ₹215.17 and ₹315.54 respectively.

It is obvious from the sensitivity analysis of the model that, several changes could be suggested to increase the farm income, if the farmer's constraints are removed or change the RHS of the constraints in terms of available resources. The shadow price values (unit worth of resources) indicates the increase or decrease in the gross returns of the LP model for a unit change in value of the constraint within the given range of minimum and maximum of RHS and the these values are presented in Table 32. In the case of expenditure, third quartile (₹28820.03/-) was taken as the RHS of investment amount for LP modeling and the sensitivity analysis reported that, if the farmer is ready to invest an amount up to ₹ 31154.85/- , for which the farmer would receive ₹1.05/- on every one rupee additional investment. The unit worth of resource of jack, gooseberry and tamarind was ₹223.08/-, ₹256.38/- and ₹259.95/- suggested that one unit increase in the population of these enterprises would enhance farm income substantially. However, the increase in the population of these enterprises or tree crops invades the concept of homesteads. While the shadow price ₹ 335.5/- of vegetable unit recommending the possibility of expanding vegetable area in the homesteads which may be more acceptable than of increasing the population of perennial tree crops.

Homestead area in the model was found to be an abundant resource with non binding constraints for area and hence the shadow price was zero. The shadow price of non binding enterprises would always be zero indicating that, the there is no meaning in increasing the abundant resources. However, an increase in the population of the enterprises having high shadow price will give more return, but at the expense of other enterprises which are more remunerative.

The optimum LP model and the sensitivity analysis of S_1 indicated that maximum net return has been achieved by increasing the population of farmer preferred enterprises in a lesser cultivated area of homesteads.

Table 31. Sensitivity analysis on objective function coefficients in S_1 of AEU 8

S.No.	Name	Final value	Objective Coefficient	Max.Range	Min. Range
1	Coconut	15	142.2	197.12	
2	Jack	2	438.25	-	215.17
3	Mango	2	406.67	-	315.54
4	Gooseberry	2	440.45	-	184.07
5	Tamarind	2	517.15	-	257.6
6	Bread Fruit	1	239.66	-	151.27
7	Cashew	2	485.32	-	458.84
8	Arecanut	3	282.21	-	134.83
9	Tapioca	108	35.61	-	33.63
10	Banana	47	190.48	201.47	151.42
11	Pepper	10	223.15	-	130.81
12	Ginger	8	7.22	-	5.24
13	Turmeric	7	6.11	9.69	-
14	Papaya	13	89.65	-	68.17
15	Moringa	2	36.8	-	24.25
16	Colocasia	5	18.62	23.42	-
17	Dioscorea	12	33.7	-	29.08
18	Amorphophallus	18	61.4	-	34.25
19	Sapota	1	142.86	184.31	-
20	Annona	1	255.23	-	199.34
21	Guava	2	558.45	-	390.25
22	Vegetables	2	3647.55	-	3312
23	Home	1	0	-	-

Table 32. Sensitivity analysis of available resources in S_1 of AEU 8.

S.No	Name	Final Value	Constraint R.H. Side	Max R.H. Side	Min R.H. Side	Shadow Price
1	Expenditure	28792.68	28820.03	31154.85	20252.56	1.05
2	Total Area	1450.48	1800	-	1642.98	0
3	Interspace	390.27	677.44	-	527.26	0
4	Home	1	1	1.41	0	0
5	Coconut	15	30	-	15	0
6	Jack	2	2	17.29	0	223.08
7	Mango	2	2	30.46	0	91.13
8	Gooseberry	2	2	11.87	0	256.38
9	Tamarind	2	2	6.46	0	259.55
10	Bread Fruit	1	1	3.38	0	88.39
11	Cashew	2	2	3.06	0	26.48
12	Arecanut	3	3	27.78	0	147.38
13	Tapioca	108	108	375.05	40	1.98
14	Banana	47	60	-	47	0
15	Pepper	10	10	78.66	0	92.34
16	Ginger	8	8	552.5	0	1.98
17	Turmeric	7	12	-	7	0
18	Papaya	13	13	143.68	5	21.48
19	Moringa	2	2	61.41	1	12.55
20	Colocasia	5	14	-	5	0
21	Dioscorea	12	12	320.88	0	4.62
22	Amorphophallus	18	18	258.66	3	27.15
23	Annona	1	1	34.01	0	55.89
24	Guava	2	2	25.01	1	168.2
25	Vegetables	2	2	4.71	1.26	335.55

4.6.2. Sensitivity Analysis of S_2 in AEU 8

Sensitivity analysis of the S_2 model of AEU 8 presented in Table 33 showed range of net income of each enterprise where, values of the enterprises in the optimal LP solution will remain unchanged within these range. It is more significant to seek out for maximum range of objective coefficient/unit net return of the enterprises having non binding solution and minimum range of enterprises with binding solutions to underline the reliability of the model. The optimal plan comprised of 4 goats and it remains valid even if the unit net income reduced to ₹4652.84/- from the net return of ₹7751.5/- in the existing plan. Similarly for black pepper, the number of pepper in the homesteads in the optimal plan remains unchanged until the unit net return reduced to half of the existing income. Home stead farmers preferred to cultivate banana (62), tapioca(80) and to rear 4 goats even if the unit net return reduced to Rs 141.68, 27.85, and 4652.84 respectively. Similar trend was noticed for all binding enterprise in the optimum model. The value of non binding enterprises like coconut and poultry suggested a limit if the net income up to ₹ 160.14 and ₹2240.4 respectively.

Sensitivity analysis on the value of RHS of linear constraints in optimal LP model presented in Table 33 revealed that, several changes could be suggest to increase the farm income, if some of the constraints are removed/modified. In the case of expenditure, third quartile was taken as the investment amount (₹63106.4/-) for developing the LP model and the farmer is ready to invest more up to ₹ 65641.09/- for which he would have received ₹0.85/- additional net return on investing every one rupee more. The maximum allowable increase and decrease of all the enterprises are also presented in Table 34 revealed that majority of the enterprises in the optimum model has achieved specified upper limit especially for tapioca, banana and black pepper. The optimum model of S_2 didn't suggest increase in population of majority of enterprises even if the shadow price were very high.

Homestead land area in the model was found to be an abundant resource and non binding and hence shadow price was observed as zero. The shadow price is always zero for non binding enterprises. However, an increase in the value of the enterprise will give more return, but only at the expense of other, more remunerative enterprises. The optimum model of S_2 suggested 33.30 per cent increase in net return over the existing plan with the use of lesser cultivable area from the specified limit in the homesteads with maximum population of the enterprises as observed from sensitivity analysis is an indication to increase the cropping intensity. This may also be viewed in different way that enhancement of farm income by increasing the population of enterprises, that have not reached the maximum allowable range in the optimum model in the recommended area.

Table 33. Sensitivity analysis on objective function coefficients in S_2 of AEU 8

S.No.	Enterprise	Final value	Objective Coefficient	Max.Range	Min. Range
1	Coconut	18 nos.	156.26	160.14	-
2	Jack	2 nos.	835.28	-	267.36
3	Mango	3 nos.	435.4	-	192.31
4	Gooseberry	2 nos.	246.18	-	171.29
5	Tamarind	2 nos.	583.11	-	252.69
6	Bread Fruit	2 nos.	254.01	-	140.78
7	Cashew	3 nos.	362.76	-	330.67
8	Tapioca	80 nos.	34.58	-	27.85
9	Clove	1 no.	512.22	-	211.6
10	Banana	62 nos.	160.55	-	141.68
11	Nutmeg	1 no.	499.53	-	321.6
12	Pepper	18 nos.	200.23	-	101.7
13	Ginger	3 nos.	7.16	-	6.26
14	Curry Leaf	1 no.	51.53	-	16.7
15	Papaya	20 nos.	103.92	-	68.01
16	Moringa	2nos.	69.79	-	52.33
17	Colocasia	5 nos.	17.36	31.82	-
18	Dioscorea	12 nos.	26.36	-	25.66
19	Amorphophallus	10 nos.	142.28	-	53.26
20	Sapota	2 nos.	202.68	-	172.74
21	Annona	2 nos.	250.92	-	221.86
22	Bilimbi	2 nos.	70.52	-	31.51
23	Guava	1 no.	270.48	-	212.13
24	Pineapple	10 nos.	16.04	-	11.34
25	Vegetables	2 nos.	2180.94	2240.4	2128.06
26	Goat	4 nos.	7751.5	-	4652.84
27	Poultry	6 nos.	865.17	1206.16	-
28	Home	1 no.	0	-	-

Table 34. Sensitivity analysis of available resources in S_2 of AEU 8.

S.No	Name	Final Value	Constraint R.H. Side	Max R.H. Side	Min R.H. Side	Shadow Price
1	Expenditure	63064.5	63106.4	65641.09	63064.45	0.85
2	Total Area	1127.31	1800	-	1127.31	0
3	Interspace	377.81	935.69	-	377.81	0
4	Home	1	1	2.71	0	0
5	Coconut	18	40	-	18	0
6	Jack	2	2	2.13	1	567.92
7	Mango	3	3	3.18	2	243.09
8	Gooseberry	2	2	2.21	0	74.89
9	Tamarind	2	2	2.14	1	330.42
10	Bread Fruit	2	2	2.25	1	113.23
11	Cashew	3	3	3.11	1	32.09
12	Tapioca	80	80	81.27	60	6.73
13	Clove	1	1	1.17	0	300.62
14	Banana	62	62	62.25	46.86	18.87
15	Nutmeg	1	1	1.11	0	177.93
16	Pepper	18	18	18.35	0	98.53
17	Ginger	3	3	8.67	0	0.9
18	Curry Leaf	1	1	3.13	0	34.83
19	Papaya	20	20	20.52	2	35.91
20	Moringa	2	2	2.68	0	17.46
21	Colocasia	5	12	-	5	0
22	Dioscorea	12	12	13.38	8	0.7
23	Amorphophallus	10	10	10.67	2	89.02
24	Sapota	2	2	2.21	1	29.94
25	Annona	2	2	2.16	1	29.06
26	Bilimbi	2	2	3.13	0	39.01
27	Guava	1	1	1.17	0	58.35
28	Pineapple	10	10	13.13	0	4.7
29	Vegetables	2	3	-	2	0
30	Goat	4	4	4.01	3.54	3098.66
31	Poultry	6	15	-	6	0

4.6.3. Sensitivity Analyses of S_3 in AEU 8

Sensitivity analysis of the S_3 model of AEU 8 revealed a minimum and maximum range of net income for each enterprise, within which, the optimal LP solution will remain unchanged (Table 35). It is more important to look for maximum range of objective coefficient/unit net return for the enterprises having non binding solution and minimum range for enterprises with binding solutions to come across the reliability of model. It is evident from the results of sensitivity analysis on the objective function coefficient that the coconut palm can be included in the model only if the unit net income reaches ₹1319.02/- but purposefully, 15 palms were added in the model. The non binding enterprises like banana and poultry may become binding enterprises if the unit net income reach above ₹169.62/- and ₹963.37/- respectively. The value of binding enterprises like gooseberry and tamarind will remain the same until the unit net return reaches a minimum of ₹99.72/- and ₹124.18/- respectively.

Sensitivity analysis on available resources of S_3 is presented in Table 36 and it suggests several changes that would help to increase the farm income, if some of the constraints are removed/ changed. The shadow price values (dual price) indicate the increase or decrease in the gross returns of the model for unit change in value of the constraint within the given range of minimum and maximum of RHS. In the case of expenditure, third quartile of the investment amount (₹1,85,695/-) is considered for LP modeling and the sensitivity analysis indicated that if the farmer is willing to invest more amount, up to ₹ 1,89,899/-, for which he would receive ₹0.97 /- on every additional rupee invested. The enterprise banana in the optimum model has a value which was minimum of the feasibility range with a shadow price zero suggested no further increase in the population of this enterprise in the model. Shadow price was highest for vegetables (Rs 1154. 03) in one cent among the enterprises indicating the need of expanding area under vegetables in the homesteads.

Homestead area in the model has been found to be an abundant resource with non binding constraints; hence shadow price is zero. The shadow price was always zero for non binding enterprises. However, rise in rate of the enterprises in the homesteads in turn provide more return, but at the expense of other enterprises which are more remunerative.

Table 35. Sensitivity analysis on objective function coefficients in S_3 of AEU 8

S.No.	Name	Final value	Objective Coefficient	Max.Range	Min. Range
1	Coconut	0(15)	162.49	1319.02	-
2	Jack	1	722.82	-	341.67
3	Mango	3	415.85	-	270.69
4	Gooseberry	2	286.03	-	99.72
5	Tamarind	1	381.41	-	124.18
6	Bread Fruit	2	289.99	-	185.31
7	Cashew	2	323.37	-	310.45
8	Tapioca	80	40.18	-	32.81
9	Banana	21	166.42	169.62	153.27
10	Pepper	8	265.82	-	168.01
11	Ginger	8	6.33	-	3.3
12	Turmeric	8	4.81	6.39	-
13	Curry Leaf	2	56.5	-	31.89
14	Papaya	10	106.11	-	66.65
15	Moringa	1	59.57	-	17.33
16	Colocasia	12	17.16	-	16.25
17	Dioscorea	9	38.45	-	28.49
18	Amorphophallus	7	84.65	-	45.8
19	Sapota	0	139.37	175.38	-
20	Annona	1	439.57	-	282.58
21	Bilimbi	1	48.42	-	36.57
22	Guava	1	417.89	-	252.45
23	Vegetables	2	4879.24	-	3732.71
24	Cow	3	40648.03	-	39880.12
25	Goat	4	8952.66	-	7798.63
26	Poultry	10	887.27	963.37	-
27	Home	1	0	-	-

Table 36. Sensitivity analysis of available resources in S_3 of AEU 8.

S.No	Name	Final Value	Constraint R.H. Side	Max R.H. Side	Min R.H. Side	Shadow Price
1	Expenditure	185695	185695	189899	185606	0.97
2	Total Area	940.6	1800	-	940.6	0
3	Interspace	265.44	1043.61	-	265.44	0
4	Home	1	1	2.96	0	0
5	Coconut	0(15)	35	-	0	0
6	Mango	3	3	3.32	0	145.16
7	Gooseberry	2	2	2.87	0	186.31
8	Tamarind	1	1	1.7	0	257.23
9	Bread Fruit	2	2	2.47	0	104.68
10	Cashew	2	2	2.28	0	12.92
11	Tapioca	80	80	82.63	0	7.37
12	Banana	20	45	-	20	0
13	Pepper	8	8	8.51	0	97.81
14	Ginger	8	8	34.22	0	3.03
15	Turmeric	8	10	-	8	0
16	Curry Leaf	2	2	4.71	0	24.61
17	Papaya	10	10	11.3	0	39.46
18	Moringa	1	1	5.98	0	42.24
19	Colocasia	12	12	17.32	0	0.91
20	Dioscorea	9	9	12.03	0	9.96
21	Amorphophallus	7	7	8.89	0	38.85
22	Sapota	0	1	-	0	0
23	Annona	1	1	1.31	0	156.99
24	Bilimbi	1	1	3.36	0	11.85
25	Guava	1	1	1.34	0	165.44
26	Vegetables	2	2	2.02	0.91	1146.53
27	Cow	3	3	3	2.9	767.91
28	Goat	4	4	4.01	3.48	1154.03
29	Poultry	10	15	-	10	0
30	Jack	1	1	1.25	0	381.15

Sensitivity analysis and the optimum LP models of all the cropping system in AEU 8 revealed that the existing homestead of an average size of 45 cents didn't require the cultivated area or net cropped area suggested which, consist of almost all the enterprise with maximum of the feasibility range of available resources. At the same time, maximum feasibility range of three unit of house and permanent structures indicated that a homestead farmer can use the underutilized cropped area for further expansion of the house. This may be recommended until all homestead family had sufficient finance for the expansion of house and permanent structure. Instead of this one can argue that expansion of underutilized area left for cropping, be planted with farmer preferred crops which in turn definitely enhance the farm family income by utilizing available resources including the family labour.

4.6.4. Sensitivity Analyses of S_1 in AEU 9

Sensitivity analysis was carried out on the S_1 model of AEU 9 presented in Table 37 suggesting the range of value of net income for each enterprise, where the value of enterprise in the optimal LP solution will remain constant. The maximum range of objective coefficient/unit net return for the enterprises having non binding solution and minimum range for enterprises with binding solutions need to be investigated so as to ascertain reliability of model. The optimal LP model has fourteen numbers when the unit net returns from coconut palm was ₹104.78/- The change in value in optimum model for coconut was recommended only if the unit net income attains above ₹124.41/-. Similarly, the maximum suggested range for cashew was ₹216.16/- and that of vegetables was ₹1914.75/- and so on. The result proved that the value of enterprises remain unchanged for most of the perennial trees even if the net income gets reduced to half of the obtainable.

Sensitivity analysis of the model revealed that, there exist certain possibilities by which farmer can increase the farm income, provided his constraints are removed. The shadow prices of the enterprises having binding and non binding solution is presented in the Table 38. The shadow prices presented in table 37 (unit worth of resources) indicated the increase or decrease in the gross returns of the model, for unit change in value of the constraint within the given range of minimum and maximum RHS. With respect to expenditure, third quartile of the investment amount (₹23384.2/-) was used for LP modeling and if the farmer is all set to put more money as investment, up to ₹ 24789.95/- , for which he would receive ₹ 0.9978/- on every additional rupee invested. Sensitivity analysis on the range of feasibility of available resources indicated that all the enterprise didn't achieved the maximum feasibility range except for banana.

Table 37. Sensitivity analysis on objective function coefficients in S_1 of AEU 9

S.No.	Name	Final value	Objective Coefficient	Max.Range	Min. Range
1	Coconut	14	104.78	124.41	-
2	Jack	2	569.46	-	222.72
3	Mango	3	562.81	-	275.5
4	Gooseberry	2	236.39	-	110.07
5	Tamarind	1	443.83	-	189.77
6	Bread Fruit	2	259.97	-	107.77
7	Cashew	1	188.98	216.16	-
8	Arecanut	0	141	-	134.4
9	Tapioca	100	38.25	-	27.35
10	Banana	47	168.17	176.43	153.03
11	Pepper	16	226.23	-	118.84
12	Ginger	7	9.26	10.18	-
13	Turmeric	10	6.34	-	3.93
14	Papaya	20	77.1	-	61.13
15	Colocasia	10	9.34	16.18	-
16	Dioscorea	6	8.93	12.84	-
17	Amorphophallus	15	56.13	-	29.66
18	Sapota	3	229.69	-	184.32
19	Bilimbi	2	55.05	-	40.56
20	Guava	2	251.77	-	162.82
21	Pineapple	7	16.34	18.66	-
22	Vegetables	2	1639.27	1914.75	-
23	Home	1	0	-	-

Table 38. Sensitivity analysis of available resources in S_1 of AEU 9.

S.No	Name	Final Value	Constraint R.H. Side	Max R.H. Side	Min R.H. Side	Shadow Price
1	Expenditure	23384.2	23384.2	24789.95	15519.96	0.9978
2	Total Area	1176.26	2100	2100	1176.255	0
3	Interspace	368.34	1091.65	1091.65	368.34	0
4	Home	1	1	3.171495	0	0
5	Coconut	14	30	30	14	0
6	Jack	2	2	37.23158	0	346.736
7	Mango	3	3	31.48216	0	287.307
8	Gooseberry	2	2	73.28822	0	126.321
9	Tamarind	1	1	25.4822	0	254.065
10	Bread Fruit	2	2	47.36567	0	152.197
11	Cashew	1	3	3	1	0
12	Arecanut	0	0	58.38488	0	6.60497
13	Tapioca	100	100	386.8813	48.71835	10.901
14	Banana	47	55	55	47	0
15	Pepper	16	16	82.03175	4.19645	107.392
16	Ginger	7	10	10	7	0
17	Turmeric	10	10	1078.25	5	2.40742
18	Papaya	20	20	148.3749	0	15.9719
19	Colocasia	10	12	12	10	0
20	Dioscorea	6	10	10	6	0
21	Amorphophallus	15	15	279.5096	0	26.4673
22	Sapota	3	3	45.57206	1	45.3719
23	Bilimbi	2	2	195.4617	1	14.4894
24	Guava	2	2	50.1929	0	88.9481
25	Pineapple	7	13	13	7	0
26	Vegetables	2	2	2	2	0

According to the developed model, area was observed to be a rich resource with non binding constraints and hence shadow price was zero. However, some enterprises had large shadow price, some had less than 100 and some had zero is an indication of increasing the population of the enterprises by giving due importance to food security and crops for house hold consumption in the underutilized area of the homesteads.

4.6.5. Sensitivity Analyses of S_2 in AEU 9

Sensitivity analysis of the S_2 model of AEU 9 was carried out and feasibility range of net income of each enterprise in the optimal LP solution was found to remain unchanged within the range, as exposed by the analysis is given in (Table 39). It is more significant to seek maximum range of objective coefficient/unit net return for the enterprises having non binding solution and minimum range for enterprises with binding solutions to assess the integrity of the model. The value of coconut in the optimal plan was eighteen in numbers when the unit net returns of coconut palm was ₹99.11/- and the model is stable or is recommended to take up more coconut palms only if the unit net income reaches above ₹120.7/-. Similarly, for banana, the maximum range was ₹159/- and that of papaya was ₹68.45/- and so on. The value of binding enterprises like jack and annona was same until the unit net return reaches a minimum of ₹48.45/- and ₹100.4/- respectively.

Sensitivity analysis conducted on RHS values of the linear constraints presented in Table 40 helped in deriving solution that incorporate certain modifications in the enterprises to enhance the farm income, if some of the constraints are removed. The shadow price values (unit worth of resources) revealed the increase or decrease in the gross returns of the model for unit change in value of the constraint within the given range of minimum and maximum RHS. In the case of expenditure, third quartile of the investment amount (₹53616/-) was used for LP modeling even if the farmer is ready to invest more up to ₹54408.2/-, for which the farm income has enhanced by ₹0.995/- on every additional rupee invested. In contradiction to S_2 in AEU 8, only very few enterprises (poultry, goat, vegetables, guava, mango etc) reached near to the maximum feasibility range in the optimal model with shadow price for poultry, vegetables, guava and mango suggesting no further increase in population of these enterprises. The major enterprises which can be increased in S_2 were tapioca upto ₹401/- with shadow price of 1.68/-, black pepper up to ₹149/- with shadow price of ₹ 82.88/- and annona up to 34 with shadow price of ₹69.56/-

Since the shadow price is zero for non binding enterprises and the zero shadow price of homestead area in the model was noticed is an indication of abundant land resource. However, more return was possible subjected to anin increase in population of the enterprises with non-zero shadow price, only at the expense of other more remunerative enterprises. Optimum plan developed, subjected to constraints consisted of 4 goats and sensitive analysis recommend that addition of 1 more goat to the model will add ₹514.85/- to the net income.

Table 39. Sensitivity analysis on objective function coefficients in S_2 of AEU 9

S.No.	Name	Final value	Objective Coefficient	Max .Range	Min. Range
1	Coconut	18	99.11	120.7	-
2	Jack	3	120.9	-	48.45
3	Mango	2	337.5	429.5	-
4	Cashew	2	148.3	-	147.6
5	Tapioca	80	31.69	-	30.01
6	Banana	45	149.8	159	-
7	Pepper	20	157.4	-	74.47
8	Turmeric	6	10.06	-	5.39
9	Curry Leaf	2	29.86	-	15.22
10	Papaya	6	63.42	68.45	-
11	Colocasia	18	19.46	-	17.01
12	Dioscorea	6	13.91	27.24	-
13	Amorphophallus	15	79.01	-	78.62
14	Annona	1	170	-	100.4
15	Bilimbi	1	29.56	-	18.72
16	Guava	1	124.2	130.6	-
17	Vegetables	4	944.9	-	-
18	Goat	4	6245	-	5730
19	Poultry	14	694.9	698.3	660.6
20	Home	1	0	-	-

Table 40. Sensitivity analysis of available resources in S_2 of AEU 9.

S.No	Name	Final Value	Constraint R.H. Side	Max R.H. Side	Min R.H. Side	Shadow Price
1	Exp	53616	53616	54408.2	43933.3	0.99506
2	Area	1409.19	2100	2100	1409.19	0
3	Interspace	432.85	1281.51	1281.51	432.85	0
4	Home	1	1	2.57057	0	0
5	Coconut	18	26	26	18	0
6	Jack	3	3	88.2584	0	72.486
7	Mango	2	3	3	2	0
8	Cashew	2	2	8.46923	0	0.73339
9	Tapioca	80	80	401.035	53.7336	1.67761
10	Banana	45	55	55	45	0
11	Pepper	20	20	149.379	9.41451	82.8767
12	Turmeric	6	6	879.51	0	4.67052
13	Curry Leaf	2	2	635.275	0	14.6414
14	Papaya	6	14	14	6	0
15	Colocasia	18	18	320.373	0	2.44936
16	Dioscorea	6	8	8	6	0
17	Amorphophallus	15	15	137.554	4.97294	0.39061
18	Annona	1	1	34.2799	0	69.5644
19	Bilimbi	1	1	152.39	0	10.8387
20	Guava	1	2	2	1	0
21	Vegetables	4	4	4	4	0
22	Goat	4	4	5.68135	3.86244	514.848
23	Poultry	14	15	15	14	0

6.6.6. Sensitivity Analyses of S_3 in AEU 9

The values of the enterprises in the optimal LP solution will remain unchanged within the range of net income expressed by sensitivity analysis conducted on the S_3 model of AEU 9 (Table 41). The maximum range of objective function coefficient/unit net return for the enterprises having non binding solution and minimum range for enterprises with binding solutions need to be looked into verify the reliability of the model. Unit net returns from coconut was estimated as ₹111.15/- and the value of coconut in the optimal plan was twenty in number. The model remains valid till the unit net return was Rs114.16/-. Similarly for mango the maximum range was ₹405.91/- above which the enterprise may become binding. All other binding enterprises like pepper remain unchanged even if the net income reduced to half to the obtainable.

Sensitivity analysis on the available resources in the optimum model indicated that, many changes to enhance the farm income, if the farmers are ready to exclude some constraints. The shadow price values (unit worth of resources) indicate the increase or decrease in the gross returns of the optimal model for a unit change in value of the constraint within the given range of minimum and maximum RHS and the results are presented in Table 42. In the case of expenditure, third quartile of the investment amount (₹175698/-) is used in LP modeling and if the farmer is willing to invest more up to ₹ 183703.1/-, for which he would receive ₹0.94/- on every additional rupee invested. The sensitivity analysis on the available resources in optimum model of S_3 in AEU 9 suggested a minimum population of zero for all enterprises except cattle, goat, banana, and coconut and mango with shadow price zero. However, the optimum model consisted of all enterprise and suggesting addition of these enterprises with positive shadow prices. The existing model had 10 poultry unit and the addition of one poultry increase the income at the rate of Rs 120. 80/-.

Homestead area in this model has been found to be a rich resource consisting of both binding and non binding enterprises, where the latter resulted zero shadow price. However, an enhancement in value of the enterprise will provide more return, in the expense of other more remunerative enterprises, which interns may influence the cropping intensity.

Table 41. Sensitivity analysis on objective function coefficients in S_3 of AEU 9

S.No.	Name	Final value	Objective Coefficient	Max.Range	Min. Range
1	Coconut	20	111.15	114.16	
2	Jack	2	550.22	-	229.07
3	Mango	1	360.19	405.91	
4	Gooseberry	2	124.61	-	91.33
5	Tamarind	1	418.71	-	189.82
6	Bread Fruit	1	210.94	-	78.84
7	Cashew	1	252.09	-	135.29
8	Arecanut	0	161.72	164.39	
9	Tapioca	85	33.64	-	27.05
10	Banana	65	162.47	-	151.56
11	Pepper	20	361.04	-	139.26
12	Ginger	4	17.35	-	12.55
13	Turmeric	0	8.9	9.29	
14	Curry Leaf	1	25.52	-	17.45
15	Papaya	8	86.95	-	70.71
16	Moringa	2	36.97	-	26.46
17	Colocasia	17	16.1	-	13.82
18	Dioscorea	15	18.35	-	13.64
19	Amorphophallus	20	101.87	-	50.95
20	Annona	1	261.48	-	209.19
21	Bilimbi	2	44.56	-	22.63
22	Guava	2	307.51	-	162.62
23	Pineapple	10	16.06	-	11.93
24	Vegetables	2	2476.52	-	1806.61
25	Cow	3	44514.2	-	39695.16
26	Goat	2	7558.08	8101.99	7435.48
27	Poultry	10	696.02	-	575.22
28	Home	1	0	-	-

Table 42. Sensitivity analysis of available resources in S_3 of AEU 9.

S.No	Name	Final Value	Constraint R.H. Side	Max R.H. Side	Min R.H. Side	Shadow Price
1	Expenditure	175660.6	175698	183703.1	159575.7	0.94
2	Area	1250.395	2100	2100	1300.42	0
3	Interspace	434.403	1109.644	1109.64	434.4	0
4	Home	1	1	2.8	0	0
5	Coconut	20	30	-	20	0
6	Jack	2	2	68.14	0	321.15
7	Mango	1	2	-	1	0
8	Gooseberry	2	2	133.21	0	33.28
9	Tamarind	1	1	59.27	0	228.89
10	Bread Fruit	1	1	49.29	0	132.1
11	Cashew	1	1	16.94	0	116.8
12	Tapioca	85	85	645.11	0	6.59
13	Banana	65	65	164.97	15.37	10.91
14	Pepper	20	20	128.8	0	221.78
15	Ginger	4	4	1211.81	0	4.8
16	Curry Leaf	1	1	337.01	0	8.07
17	Papaya	8	8	222.27	0	16.24
18	Moringa	2	2	129.25	0	10.51
19	Colocasia	17	17	353.01	0	2.28
20	Dioscorea	15	15	612.35	0	4.71
21	Amorphophallus	20	20	317.4	0	50.92
22	Annona	1	1	73.43	0	52.29
23	Bilimbi	2	2	440.87	0	21.93
24	Guava	2	2	71.42	0	144.89
25	Pineapple	10	10	1279.65	0	4.13
26	Vegetables	2	2	10.39	0	669.91
27	Cow	3	3	3.38	2.81	4819.03
28	Goat	2	3	-	2	0
29	Poultry	10	10	36.34	0	120.8

Summary

CHAPTER V

SUMMARY

Homestead farming has been the backbone agricultural economy of Kerala, owing to its direct and indirect benefits to the social and economic well being of the people in state over the years, both at the micro and macro levels. The homesteads of Kerala, which once considered the self sustainable mini-production models is at the verge of extinction due to the share of land under homestead farming in Kerala has grown, and the share of area under garden land has declined, owing to rapid urbanization. Over the years, many small holdings have fragmented into smaller homesteads. Farmers depending on farming alone were found in distress due to low and fluctuating income. Increasing population and low per capita availability of lands have necessitated better management practices in home gardens and the micro-development models like homesteads is the key to success in a populous country like India.

The present study entitled 'Statistical models for profit maximization of homesteads in Kerala' was carried out with the objectives of examining and developing statistical models for homestead farming systems in the southern and south central laterite agro-ecological units (AEU8 and AEU9) of Thiruvananthapuram district and to suggest suitable cropping/farming system models that maximize farm income by the optimal use of available resources.

The study was based on the primary data. The relevant data from forty randomly selected homesteads of almost similar cropping systems and having area 0.1 ha to 0.3 ha from two panchayaths (Kulathoor and Karode) of AEU8 and same number of homesteads from two panchayaths (Anad and Vembayam) of AEU9 was collected using a well-structured pre-tested interview schedule. The input-output data pertains to the agriculture year 2016-17.

Statistical tools such as ratios, percentages and frequencies were applied to socio-economic variables and descriptive statistics were worked out to summarize homestead characteristics. The selected coconut based homesteads were grouped into three on the basis of cropping/farming system existing in the homesteads (HFS), viz. system-I (S_1) consisting of crops alone, system-II (S_2) including crops, poultry and goat and system-III (S_3) comprising of crops, poultry and all livestock. The optimum model was developed by using linear programming (LP) technique with the linear objective function $Z = c_1x_1 + c_2x_2 + ... + c_nx_n$, where $x_1, x_2, \ldots, x_n$ are the variables used to denote the enterprises and $c_1, c_2, \ldots, c_n$ are the unit net return associated to each enterprise. The constraints included in the analysis were total area, intercropped area, investment amount and population of each enterprise. The optimum model was developed by giving more emphasis to safe to eat vegetable cultivation by at least doubling the area under vegetable cultivation over the existing plan and by providing adequate number of coconut palms based on farmer's preferences for this enterprise.

- It was found that 43.75 per cent of the respondents belonged to the middle aged category having secondary and higher secondary level of education (47.5%) with an annual income less than ₹ 4 lakhs (77.5%) and having median family size of 5.

- Only 12.5 per cent and 17.5 per cent of the respondents in AEU8 and AEU9 had agriculture as main source of income while majority had agriculture as subsidiary income in both agro-ecological units.

- Majority of the homesteads in AEU8 (82.5%) and AEU9 (92.5%) were semi-irrigated.

- The average size of homesteads was 0.18 ha and 0.21 ha in AEU8 and AEU9 respectively.

- The selected homesteads followed coconut based cropping system and comprised of other thirty eight enterprises falling under the groups namely tubers, commercial crops, spices and condiments, stimulants, fruits, vegetables, livestock and poultry.
- 100 per cent homesteads in AEU 8 and AEU 9 had coconut palms between 4 to 56 numbers which suggest that coconut based homesteads were prominent in these regions.
- Perennial fruit trees such as mango, jack, papaya and annual fruit trees such as banana were grown in most of the homesteads.
- Tuber crops were found to be the most dominant category, and among the tropical tubers, tapioca was found in almost 90 per cent of the homesteads in both agro ecological units. Other tuber crops grown in the homesteads were colocasia, dioscorea and amorphophallus.
- The commonly grown vegetables were chilli, curry leaf, ladies finger, bitter gourd, bread fruit, ivy gourd, moringa, tomato, brinjal, bottle gourd, long bean and amaranthus , mainly used for household consumption. Farmer's preference was observed in crops like banana and black pepper.
- Black pepper was grown on living standards trees such as coconut, banana *etc.*
- The number of livestock such as cow, buffalo and goat etc. reared was found to be very less. The household as a whole preferred to rear poultry. This could be due to changing consumption habit of people from vegetables to meat and egg.
- Economics of cultivation including operational cost, gross return, net return and benefit-cost ratio of all enterprises were worked out for average land holding size of 45 cents for AEU 8 and 52.5 cents for AEU 9.

- In AEU 8, the estimated total net return of the existing homestead cropping/ farming systems, S_1, S_2 and S_3 of the average size of 45 cents was ₹ 27,596/-, ₹ 55,244/- and ₹ 1,72,245/-. In AEU 9, it was ₹ 23,303/-, ₹ 34,272/- and ₹ 1,31,516/- in S_1, S_2 and S_3 systems respectively with an average holing size of 52.5 cents.

- The optimum model developed for a homestead farmer in S_1 of AEU 8 by investing an amount of ₹ 28,793/- , would receive a net profit of ₹ 34,577/- which indicates 25.30 per cent enhancement in net profit over the existing plan. The optimum model left main area of 439.79 m^2 with and unutilized interspaced area of 390.27 m^2.

- The optimum model of LP consisted of all enterprises with binding solution in the sense that the populations of the enterprises are same as the RHS of linear inequality constraints except for major enterprises coconut and banana. The optimum model suggested a minimum number of 15 coconut palms, banana (47 nos.), tapioca (108 nos.), and vegetables two units along with other crops.

- The livestock/poultry unit in the optimum model in S_2 comprised of 4 goats and 6 poultry birds. In the optimum model, goat unit has a great role in increasing the farm income by way of selling kids and poultry unit in most of the S_2 homesteads providing eggs and meat required for the farm family.

- The population constraint for coconut as per the preference of farmers was within a range of 18 to 30 palms. The optimum model suggested cultivation of minimum number of coconut palms keeping in view, other constraints, land requirement and investment amount. The optimal solution for coconut, i, poultry and vegetables did not allow increasing the population up to suggested limit, due to the constraint of scarce available investment capital. The optimum model worked out for S_2 in AEU 8 was found to have binding solution for almost all the enterprises except some enterprises

- The optimum LP model developed by investing an amount of ₹ 63,060/-.in S_2 farmer household would receive a net profit of ₹ 72,536/- which indicates an enhancement of 31.30 per cent in net return as compared to the net return of the existing plan. However, the available area in the homestead was underutilized by all enterprises including area under house and permanent structures in the optimum model with two vegetable units.
- The optimum model for S_3 homesteads in AEU 8 was developed by investing an amount of ₹ 1,88,331/-. The farmer would obtain a net profit of ₹ 1,95,183/- which shows an enhancement of 13.31 per cent in net return as compared to the net return of the existing plan. The optimum model worked out for S_3 in AEU 8 was found to have binding solution for almost all the enterprises except some enterprises like banana, poultry and turmeric with B:C ratio of 2.04.
- The optimum model for S_1 in AEU 9 was developed by investing an amount of ₹ 23,384/- would receive a net profit of ₹ 28,624/- indicating 22.83 per cent enhancement in net return as compared to net return from the existing plan. The model worked out for S_1 in AEU 9 was found to have non binding solution for enterprises such as coconut, cashew, ginger, dioscorea, pineapple and banana but binding solution for all other enterprises with B:C ratio of 2.22. The optimum model for average S_1 homesteads in AEU 9 comprising of 23 enterprises including house and permanent structures.

- The optimum model designed for a homestead farmer in S_2 of AEU 9 by investing an amount of ₹ 53,616/-, farmer would receive a net profit of ₹ 56,476/- which showed an enhancement of 64.79 per cent in net return as compared to that from the existing plan. In the model, non binding solution was obtained for enterprises such as coconut, mango, banana, papaya, dioscorea, guava and poultry and binding solution for rest of the enterprises, with B: C ratio of 2.05.

- The optimum model developed for homestead farmer in S_3 of AEU 9 by investing an amount of ₹ 1,88,331/-, farmer would receive a net profit of ₹ 1,90,614/- indicating 44.94 per cent increase in net return over the existing plan. The optimum model developed for S_3 in AEU 9 had binding solution for almost all the enterprises except coconut and mango with B :C ratio of 2.09.

- The result of LP indicated that intercropping area was an abundant resource in the optimal plan of all cropping /farming systems. It was also found that even if income from livestock was high, farmers preferred to have the intercrops and allied enterprises which need less management practices and labour.

- Sensitivity analysis of the S_1 model of AEU 8 suggested that the population of coconut palms in the optimal plan remains stable until the unit net income reaches ₹ 197.12/-. Similarly for banana and turmeric, the maximum allowable increase in unit net return was ₹ 201.47/- and ₹ 9.69/- respectively. In the case of binding enterprises jack and mango, the population will be same until the unit net return reduces to ₹ 215.17/- and ₹ 315.54/- respectively.

- If the S_1 homestead farmer is ready to invest an amount up to ₹ 31154.85/- , for which the farmer would receive ₹ 1.05/- on every one rupee additional investment. The unit worth of resource of jack, gooseberry and tamarind was

₹ 223.08/-, ₹ 256.38/- and ₹ 259.95/- suggested that one unit increase in the population of these enterprises would enhance farm income substantially. The shadow price of ₹ 335.5/- of vegetable unit recommending the possibility of expanding vegetable area in the homesteads.

- The sensitivity analysis of S_2 in AEU 8 suggested that 4 goats in the optimal plan remains valid even if the unit net return reduced to ₹ 4652.84/- from the net return of ₹ 7751.5/- in the existing plan. Similarly for black pepper, the number of pepper in the homesteads in the optimal plan remains unchanged until the unit net return reduced to half of the existing income. Homestead farmers preferred to cultivate banana (62 nos.), tapioca (80 nos.), vegetables (4 units) even if, the unit net return reduced to ₹ 141.68/-, ₹ 27.85/-and ₹ 4652.84/- respectively. Similar trend was noticed for all binding enterprise in the optimum model. The value of non binding enterprises like coconut and poultry suggested model validity if the net income up to ₹ 160.14/- and ₹ 2240.4/- respectively.

- If the farmer is ready to invest more up to ₹ 65,641/- for which he would have receive ₹ 0.85/- additional net return on investing every one rupee more. The majority of the enterprises in the optimum model have achieved the upper limit specified particularly for tapioca, banana and black pepper. The optimum model of S_2 didn't suggest increase in population of majority of enterprises even if the shadow prices were very high.

- In S_3 AEU 8, if the farmer is willing to invest more amount, up to ₹ 1,89,899/-, for which he would receive ₹ 0.97 /- on every additional rupee invested. The enterprise banana in the optimum model has a value which was minimum of the feasibility range with a shadow price zero suggested no further increase in the population of this enterprise in the model. Among the crop enterprises, shadow price was highest for vegetables (₹ 1146.53/-) in one cent indicating the need of expanding area under vegetables in the homesteads. It is evident from the results of sensitivity analysis on the objective function coefficient of coconut that 15 palms included purposefully in the model remains unchanged if the unit net income reaches up to ₹ 1319.02/-.

- The non binding enterprises like banana and poultry may become binding enterprises if the unit net income reaches above ₹ 169.62/- and ₹ 963.37/- respectively. The value of binding enterprises like gooseberry and tamarind will remain the same until the unit net return reaches a minimum of ₹ 99.72/- and ₹ 124.18/- respectively

- In S_1 of AEU 9 the change in population of coconut palms in optimum model is recommended only if the unit net income from coconut palm attains above ₹ 124.41/-. Similarly, the maximum suggested range for cashew was ₹ 216.16/- and that of vegetables was ₹ 1,914.75/-. The result proved that the value of enterprises remains unchanged for most of the perennial trees even if the net income gets reduced to half of the obtainable.

- If a farmer in S_1 of AEU 9 is willing investment a capital, up to ₹ 24,789.95/- on which the farmer would receive ₹ 0.9978/- on every additional rupee invested. The maximum suggested range for cashew was ₹ 216.16/- and that of vegetables was ₹ 1914.75/- . The result proved that the value of enterprises remains unchanged for most of the perennial trees even if the net income gets reduced to half of the obtainable.

- Homestead farmer in S_2 of AEU 9, if ready to invest more up to ₹ 54,408.2/-, the farm income of the farmer was enhanced by ₹ 0.995/- on every additional rupee invested. In contradiction to S2 in AEU 8, only very few enterprises (poultry, goat, vegetables, guava, mango *etc*) reached near to the maximum feasibility range in the optimal model with shadow price zero for poultry, vegetables, guava and mango suggesting no further increase in population of these enterprises. The major enterprises which can be increased in S_2 were tapioca up to 401 with shadow price of 1.68, black pepper up to 149 with shadow price of Rs 82.88/- and annona up to34 with shadow price of ₹ 69.56/-.

- Sensitivity analysis on the range of feasibility of available resources indicated that all the enterprise didn't achieved the maximum feasibility range except for banana. Eighteen coconut palm in optimum model valid only if the unit net income reaches above ₹ 120.7/-. Similarly, for banana, the maximum range was ₹ 159/- and that of papaya was ₹ 68.45/-. The value of binding enterprises like jack and annona was same until the unit net return reaches a minimum of ₹ 48.45/- and ₹ 100.4/- respectively.

- Optimum plan developed for S_2 of AEU 9 subjected to constraints consisted of 4 goats and sensitive analysis recommend that addition of 1 more goat to the model will add ₹ 514.85/- to the net income.

- The suggested unit net returns of coconut was estimated as ₹ 114.15/- and twenty coconut palms were in the optimal plan of S_3 of AEU 9. Similarly for mango the maximum range was ₹ 405.91/ above which the enterprise may become binding. The value of binding enterprises like pepper remains unchanged even if the net income reduced to half of the obtainable.

- The shadow price values (unit worth of resources) indicate the increase or decrease in the gross returns of the model for unit change in value of the constraint within the given range of minimum and maximum RHS. In the case of expenditure, an investment more up to ₹ 1,83,703./-, by the homestead farmer for which he receive ₹ 0.94/- on every additional rupee invested.

- Homestead area in the model of all the cropping system has been found to be a rich resource and non binding constraint which resulted in zero shadow prices. However, an enhancement in the population of the enterprise will provide more return, but at the expense of other more remunerative enterprises.

Plate 3. Conducting Homestead Survey

Plate 4. Homestead Model for Kerala

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CHAPTER VI

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Abstract

STATISTICAL MODELS FOR PROFIT MAXIMIZATION OF HOMESTEADS IN KERALA

by

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Abstract of the thesis

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ABSTRACT

Statistical Models for Profit Maximization of Homesteads in Kerala

The research programme entitled 'Statistical models for profit maximization of homesteads in Kerala' was carried out with the objectives of examining and developing statistical models for homestead farming systems in the southern and south central laterite agro-ecological units (AEU8 and AEU9) of Thiruvananthapuram district and to suggest suitable cropping/farming system models that maximize farm income by the optimal use of available resources. The study was based on the primary data. The relevant data from forty randomly selected homesteads of almost similar cropping systems and having area 0.1 ha to 0.3 ha from two panchayaths (Kulathoor and Karode) of AEU8 and same number of homesteads from two panchayaths (Anad and Vembayam) of AEU9 was collected using a well-structured pre-tested interview schedule.

Statistical tools such as ratios, percentages and frequencies were applied to socio-economic variables and descriptive statistics were worked out to summarize homestead characteristics. It was found that 43.75 per cent of the respondents belonged to the middle aged category having secondary and higher secondary level of education (47.5%) with an annual income less than ₹4 lakhs (77.5%) and having median family size of 5. Only 12.5 per cent and 17.5 per cent of the respondents in AEU8 and AEU9 had agriculture as main source of income while majority had agriculture as subsidiary income in both agro-ecological units. Majority of the homesteads in AEU8 and AEU9 were semi-irrigated.

The average size of homesteads was 0.18 ha and 0.21 ha in AEU8 and AEU9 respectively. The selected homesteads followed coconut based cropping system and comprised of other thirty eight enterprises falling under the groups namely tubers, commercial crops, spices and condiments, stimulants, fruits, vegetables, livestock and poultry. The selected coconut based homesteads were grouped into three on the basis of cropping/farming system existing in the homesteads (HFS), viz. system-I

(S_1) consisting of crops alone, system-II (S_2) including crops, poultry and goat and system-III (S_3) comprising of crops, poultry, goat and livestock.

Economics of cultivation including operational cost, gross return, net return and benefit-cost ratio of all enterprises were worked out and the estimated total net return of the existing HFS for an average (45 cents) of S_1, S_2 and S_3 was ₹27,596/-, ₹55,244/- and ₹1,72,245/- in AEU8 and ₹23,303/-, ₹34,272/-and ₹1,31,516/- in AEU9 (52.5 cents) respectively. The optimum model was developed by using linear programming (LP) technique with the linear objective function $Z = c_1x_1 + c_2x_2 + ... + c_nx_n$, where $x_1, x_2, \ldots, x_n$ are the variables used to denote the enterprises and $c_1, c_2, \ldots, c_n$ are the unit net return associated to each enterprise. The constraints included in the analysis were total area, intercropped area, investment amount and population of each enterprise. The optimum model was developed by giving more emphasis to safe to eat vegetable cultivation by at least doubling the area under vegetable cultivation over the existing plan and by providing adequate number of coconut palms based on farmer's preferences for this enterprise.

The optimum model worked out for S_I in AEU8 consisted of binding solution for almost all the enterprises except some enterprises like coconut and banana with 25.30 per cent enhancement in net return as compared to net return from the existing plan. The optimum model for S_2 HFS was also similar to that of S_1 with non-binding solution for coconut and poultry with 31.30 per cent increase in net return. However, the optimum model for S_3 HFS had non-binding solution for coconut and banana as compared to the existing model and this provided only13.31 per cent increase in net return. The result of LP for S_1, S_2, S_3 HFS's in AEU9 was in accordance to AEU8 with slight difference in the nonbinding enterprises, but the increase in net return based on the optimum model in S_1, S_2 and S_3 was 22.83 per cent, 64.79 per cent and 44.94 per cent respectively. The result of LP indicated that intercropping area was an abundant resource in the optimal plan of all cropping systems. It was also found that even if income from livestock was high, farmers preferred to have the intercrops and allied enterprises which need less management practices and labour.

Sensitivity analysis of the optimum model revealed that enhancement of net return in both agro-ecological regions could be achieved by increasing the cropping intensity in the underutilized intercropped area and changing the binding enterprises.

The present study developed statistical models for the existing cropping systems in homesteads and LP model suggests that farm income could be further enhanced by growing more number of farmer preferred crops such as tapioca, banana, pepper *etc.,* and by removing the most uneconomical and less important enterprises in the existing plan with due importance to food security.

Appendices

APPENDIX – I

INTERVIEW SCHEDULE

- AEU No. & Village Name : -

I. General Information:

1. Name & address of the farmer :-

2. Biographical Details :-

Sl. No	Family Members	Sex	Relation	Age	Education	Occupation		Income
						Main	Subsidiary	
1.								
2.								
3.								
4.								
5.								
6.								

3. Asset Details :-

Sl.No`	Asset	Size	Value	Income
1.	Land a) Total b) Net cropped area			
2.	Livestock a) b)			
3.	Others (Specify)			

III. Particulars of Crop Production:-

Sl.No	Crops	Area under/ No. of Trees	Annual production Quantity		Own Consumption		Sales		Average Price	
			P	BP	P	BP	P	BP	P	BP
	COCONUT									
	JACK									
	MANGO									
	Tapioca									
	Banana									
	Papaya									
	Vegetables									
	Others (Specify)									

P= Product, BP= Byproduct

III. Cost of Production:-

➢ **Name of the Crop:-**

a. Labour (Man power) and Cost (Hired & familywise):

Sl. No	Nature of work	No. of hours employed/day		No. of days employed/month		Wage paid (Rs)	Total (Rs)
		Family	Hired	Family	Hired		
1.	Land Preparation						
2.	Seeds and Sowing						
3.	Nursery Raising						
4.	Transplanting						
5.	Water management						
6.	Fertilizer						
7.	Management						
8.	Plant protection						
	a. Weed control						
	b. Insert control						
	c. Disease control						
9.	Harvesting						
10.	Post harvesting						
11.	Marketing						
12.	Others (Specify)						

b. **<u>Cost of Seeds, Fertilizers, Plant Protection Materials etc. :</u>**

Sl.No	**Items**	**Volume**	**Source**	**Cost**
1.	Seeds			
	a. Local			
	b. High Yielding			
2.	Fertilizers			
	a. Organic			
	b. Inorganic Plant			
	ProtectionMaterials			
3.				
	Others			
	a. Transport			
	b. Interest charges			
	c. Machine Hiring			
	d. Others (Specify)			

Remarks: -

III. Details of Livestock (Animals) possessed:

Sl. No	Species	No	Present Value of the animal
	Cow		
	Buffalo		
	Goat		
	Poultry		

IV. Cost of Production (Milk, Eggs, Meat):

a. Cost of Feeding:

Sl.No	Type of feed	Source Home/Purchase	Quantity	Value
1.	Concentrates			
	a. Oil cakes			
	b. Compound Feed			
2.	Fodder			
	a. Grass			
	b. Straw			
3.	Household Inputs			
4.	Others (Specify)			

b. **Labour (Man power) and Cost (Hired & Familywise):**

Sl. No	Nature of work	No. of hours employed/day		No. of days employed/month		Wage paid (Rs)	Total (Rs)
		Family	Hired	Family	Hired		
1.	Management						
	Adult						
	Young one						
2.	Breeding						
3.	Feeding& Watering						
	Concentrate						
	Fodder						
4.	Disease control						
5.	Milking						
6.	Milk products						
7.	Marketing						
8.	Supervision						
9.	Others						

c. **Other Expenditures:**

Sl. No	Type	Cost Involved
1.	Veterinary Expenses including breeding, treatments etc.	
2.	Expenses of Utensils, baskets etc.	
3.	Any other (Specify)	
	Total	

V. Details of Milk Production and marketing:

Sl.No	No. of Animals		Milk	Marketing Expenses			
		Average yield per Day	**Value**	**v**	**vi**	**vii**	**viii**
	Cow						
	Buffalo						
	Goat						

v – Transportation, vi – Processing, vii – Labour, viii – Others

Remarks: -

APPENDIX – II

FARMERS PRICE OF AGRICULTURAL PRODUCTS PER KILOGRAM

Items	Price/KG
Coconut	29
Wild Jack	10
Jack (varikka)	95
Mango	26
Gooseberry	60
Tamarind	40
Bread Fruit	17
Cashew	110
Arecanut	90
Tapioca	23
Clove	440
Banana	326
Nutmeg	375
Pepper	450
Ginger	45
Turmeric	80
Curry Leaf	20
Papaya	22
Moringa	43
Colocasia	50
Dioscorea	40
Amorphophallus	35
Sapota	50
Annona	100
Bilimbi	15
Guava	60
Pineapple	27
Chilli	40
Ladies Finger	25
Bitter Gourd	30
Ivy Gourd	28
Tomoto	25
Brinjal	26
Bottle Gourd	15
Amaranth	20
Long Bean	33

APPENDIX – III

OBJECTIVE FUNCTION OF S_1 – AEU 8

$$\text{Maximize } Z = \begin{bmatrix} 142 \\ 438 \\ 406 \\ 440 \\ 517 \\ 240 \\ 485 \\ 282 \\ 36 \\ 190 \\ 223 \\ 7 \\ 6 \\ 90 \\ 37 \\ 19 \\ 34 \\ 61 \\ 143 \\ 256 \\ 559 \\ 3648 \\ 0 \end{bmatrix}^T \times \begin{bmatrix} coconut \\ jack \\ mango \\ gooseberry \\ tamarind \\ breadfriut \\ cashew \\ arecanut \\ tapioca \\ banana \\ pepper \\ ginger \\ turmeric \\ papaya \\ moringa \\ colocasia \\ dioscorea \\ amorphophallus \\ sapota \\ annona \\ guava \\ vegetables \\ house \end{bmatrix}$$

Subjected to,

1. Investment amount $\leq$ ₹ 28,820/-
2. Total area available $\leq 1800m^2$
3. Interspace available $\leq 677.44m^2$
4. Population of enterprises (farmers preference)

APPENDIX – IV

OBJECTIVE FUNCTION OF S_2 – AEU 8

$$\text{Maximize } Z = \begin{bmatrix} 156 \\ 835 \\ 435 \\ 246 \\ 583 \\ 254 \\ 363 \\ 35 \\ 161 \\ 500 \\ 200 \\ 7 \\ 52 \\ 104 \\ 70 \\ 17 \\ 26 \\ 142 \\ 203 \\ 251 \\ 270 \\ 16 \\ 2181 \\ 7752 \\ 865 \\ 0 \end{bmatrix}^T \times \begin{bmatrix} coconut \\ jack \\ mango \\ gooseberry \\ tamarind \\ breadfriut \\ cashew \\ tapioca \\ banana \\ nutmug \\ pepper \\ ginger \\ curryleaf \\ papaya \\ moringa \\ colocasia \\ dioscorea \\ amorphophallus \\ sapota \\ annona \\ guava \\ pineapple \\ vegetables \\ goat \\ poultry \\ house \end{bmatrix}$$

Subjected to,

1. Investment capacity $\leq$ ₹ 63,106/-
2. Total area available $\leq 1800\text{m}^2$
3. Interspace available $\leq 935.69\text{m}^2$
4. Population of enterprises

   (farmers preference)

APPENDIX – V

OBJECTIVE FUNCTION OF S_3 – AEU 8

$$\text{Maximize } Z = \begin{bmatrix} 162 \\ 723 \\ 416 \\ 286 \\ 381 \\ 290 \\ 323 \\ 40 \\ 166.42 \\ 266 \\ 6 \\ 57 \\ 106 \\ 60 \\ 17 \\ 38 \\ 85 \\ 139 \\ 440 \\ 418 \\ 4879 \\ 40648 \\ 8953 \\ 887 \\ 0 \end{bmatrix}^T \times \begin{bmatrix} coconut \\ jack \\ mango \\ gooseberry \\ tamarind \\ breadfriut \\ cashew \\ tapioca \\ banana \\ pepper \\ ginger \\ curryleaf \\ papaya \\ moringa \\ colocasia \\ dioscorea \\ amorphophallus \\ sapota \\ annona \\ guava \\ vegetables \\ cattle \\ goat \\ poultry \\ house \end{bmatrix}$$

Subjected to,

1. Investment capacity ≤ ₹ 1.85,694/-
2. Total area available ≤ $1800 m^2$
3. Interspace available ≤ $1043.61 m^2$
4. Population of enterprises

   (farmers preference)

APPENDIX – VI

OBJECTIVE FUNCTION OF S_1 – AEU 9

$$\text{Maximize } Z = \begin{bmatrix} 105 \\ 569 \\ 463 \\ 236 \\ 444 \\ 260 \\ 189 \\ 38 \\ 168 \\ 226 \\ 9 \\ 6 \\ 77 \\ 9 \\ 9 \\ 56 \\ 230 \\ 55 \\ 252 \\ 16 \\ 1639 \\ 0 \end{bmatrix}^T \times \begin{bmatrix} coconut \\ jack \\ mango \\ gooseberry \\ tamarind \\ breadfriut \\ cashew \\ tapioca \\ banana \\ pepper \\ ginger \\ turmeric \\ papaya \\ colocasia \\ dioscorea \\ amorphophallus \\ sapota \\ bi\lim bi \\ guava \\ pineapple \\ vegetables \\ house \end{bmatrix}$$

Subjected to,

1. Investment capacity ≤ ₹ 23,384 /-
2. Total area available ≤ 2100m^2
3. Interspace available ≤ 1091.65 m^2
4. Population of enterprises

   (farmers preference)

APPENDIX – VII

OBJECTIVE FUNCTION OF S_2 – AEU 9

$$\text{Maximize } Z = \begin{bmatrix} 99 \\ 121 \\ 338 \\ 32 \\ 150 \\ 157 \\ 10 \\ 63 \\ 19 \\ 14 \\ 79 \\ 30 \\ 124 \\ 945 \\ 6245 \\ 695 \\ 0 \end{bmatrix}^T \times \begin{bmatrix} coconut \\ jack \\ mango \\ tapioca \\ banana \\ pepper \\ turmeric \\ papaya \\ colocasia \\ dioscorea \\ amorphophallus \\ bi\lim bi \\ guava \\ vegetables \\ goat \\ poultry \\ house \end{bmatrix}$$

Subjected to,

1. Investment capacity $\leq$ ₹ 53,616 /-
2. Total area available $\leq 2100\text{m}^2$
3. Interspace available $\leq 935.69\text{m}^2$
4. Population of enterprises

   (farmers preference)

APPENDIX – VII

OBJECTIVE FUNCTION OF S_3 – AEU 9

$$\text{Maximize } Z = \begin{bmatrix} 111 \\ 550 \\ 360 \\ 125 \\ 419 \\ 211 \\ 252 \\ 34 \\ 162 \\ 361 \\ 17 \\ 9 \\ 87 \\ 37 \\ 16 \\ 18 \\ 102 \\ 261 \\ 45 \\ 308 \\ 16 \\ 2477 \\ 44515 \\ 7558 \\ 696 \\ 0 \end{bmatrix}^T \times \begin{bmatrix} coconut \\ jack \\ mango \\ gooseberry \\ tamarind \\ breadfriut \\ cashew \\ tapioca \\ banana \\ pepper \\ ginger \\ turmeric \\ papaya \\ moringa \\ colocasia \\ dioscorea \\ amorphophallus \\ annona \\ bi\lim bi \\ guava \\ pineapple \\ vegetables \\ cattle \\ goat \\ poultry \\ house \end{bmatrix}$$

Subjected to,

1. Investment capacity ≤ ₹1,76,958 /-
2. Total area available ≤ 2100m^2
3. Interspace available ≤ 1109.64m^2
4. Population of enterprises

   (farmers preference)