DIVERSITY, STRUCTURE AND STANDING STOCK OF TIMBER IN THE HOMEGARDENS OF THRISSUR DISTRICT, KERALA

By

SUBU R UNNITHAN

(2014-17-109)

THESIS

Submitted in partial fulfilment of the requirement for the degree of

MASTER OF SCIENCE IN FORESTRY

FACULTY OF FORESTRY

KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF SILVICULTURE AND AGROFORESTRY

COLLEGE OF FORESTRY

VELLANIKKARA, THRISSUR – 680 656

KERALA, INDIA

2017

DECLARATION

I, hereby declare that this thesis entitled "Diversity, structure and standing stock of timber in the homegardens of Thrissur district, Kerala" is a bonafide record of research done by me during the course of research and that 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.

Vellanikkara

Date:

SUBU R UNNITHAN

2014 - 17 - 109

Date:

Dr. T. K. Kunhamu
Professor and Head
Department of Silviculture and Agroforestry
College of Forestry
Kerala Agricultural University
Vellanikkara, Thrissur, Kerala

CERTIFICATE

Certified that this thesis entitled "Diversity, structure and standing stock of timber in the homegardens of Thrissur district, Kerala" is a record of research work done independently by **Mr. Subu R Unnithan (2014-17-109)** under my guidance and supervision, it has not previously formed the basis for the award of any degree, diploma, fellowship or associateship to him.

Vellanikkara

Dr. T. K. Kunhamu
Major advisor
Advisory Committee

CERTIFICATE

We, the undersigned members of the Advisory Committee of **Mr. Subu R Unnithan (2014-17-109)**, a candidate for the degree of **Master of Science in Forestry,** agree that this thesis entitled "Diversity, structure and standing stock of timber in the homegardens of Thrissur district, Kerala" may be submitted by him in partial fulfillment of the requirement for the degree.

Dr. T. K. KUNHAMU
Professor and Head
Department of Silviculture and Agroforestry
College of Forestry
Vellanikkara, Thrissur
(Chairman)

Dr. V. JAMALUDHEEN
Associate Professor
Department of Silviculture and Agroforestry
College of Forestry
Vellanikkara, Thrissur
(Member)

Dr. E.V. ANOOP
Professor and Head
Department of Wood Science
College of Forestry
Vellanikkara, Thrissur
(Member)

Dr. A.V. SANTHOSH KUMAR
Professor and Head
Department of Tree Physiology and Breeding
College of Forestry
Vellanikkara, Thrissur
(Member)

EXTERNAL EXAMINER
Dr. Ramakrishna Hegde
Professor and Head
Department of Silviculture and
Agroforestry, College of Forestry
University of Agriculture and
Horticultural sciences, Shimoga

ACKNOWLEDGMENT

In the first place I would like to record my sincere gratitude to my project advisor, **Dr. T.K Kunhamu**, Professor and Head, Department of Silviculture and Agroforestry, College of Forestry, Vellanikkara and major advisor of my advisory committee for his sustained and valuable guidance, unstinted support, timely help, advice, unfailing patience, friendly approach and his unflinching encouragement that helped me to get through the agonising period in the most positive way.

I extend my whole-hearted gratitude to **Dr. V. Jamaludheen**, Associate Professor and member of my advisory committee for his whole-hearted co-operation, immense help and valuable suggestions provided during the course of my study.

I express my heartfelt gratitude to **Dr. E.V. Anoop**, Professor and Head, Department of Wood Science, College of Forestry, Vellanikkara and member of my advisory committee for his co-operation and support rendered throughout this work.

I express my heartfelt gratitude to **Dr. A.V. Santhosh Kumar**, Professor and Head, Department of Tree Physiology and Breeding, College of Forestry, Vellanikkara and member of my advisory committee for her co-operation, support rendered throughout this work.

I would like to acknowledge the academic and technical support provided by the Kerala Agricultural University and my esteemed institution, the College of Forestry in the successful completion of my studies and thesis work.

I owe my sincere thanks to **Dr. Sunanda C**, Assistant Professor, Department of Statistics, CVAS, Pookode and **Miss Jayasree Unnikrishnan**, Teaching Assistant, Department of Wildlife science, COF, Vellanikkara for their valuable guidance and timely help during analysis of my collected data.

I owe my sincere thanks to **Dr. K. Vidyasagaran**, Dean, College of Forestry, Vellanikkara for granting permission to carry out my project work and providing nice working environment.

I express my heartfelt thanks to **Thanku, Nimmi, Thoppan, Gaki, Hitha P.T, Anju T, Krikku, Nadha and Sana of 2013 batch, Eldhose, Ranjith Palandi, Ilyas, Badusha of 2012 batch, Azhar Ali, Vivek Noel and Afthab of 2014 batch, Devu of 2015 batch** and my seniors **Binu, Anoob, Bill, Jiljith** and all my seniors and juniors for their valuable guidance and timely help during various stages of my work.

Words cannot express the true friendship and help that I relished with my dearest batch mates **Sreejith, Akhil, Alex, Aravind, Swathy, Deepak, Toji, Aswathy, Devi priya, Reshma, Anees, Neenu, Lakshmi and Devika** of 2014 MSc batch.

Above all I bow my head before my Family, and GOD, who blessing enabled me to undertake this venture successfully.

SUBU R UNNITHAN

CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

App. No.	Title
I	Questionnaire used for the socio-economic survey in selected homegardens of Thrissur district, Kerala
II	List of all tree species identified from surveyed homegardens of Thrissur district with their functional groups
III	List of all agricultural crop species identified from surveyed homegardens of Thrissur district

INTRODUCTION

INTRODUCTION

The traditional agricultural practices in Kerala involve integration of diverse tree crops along with agriculture. Probably the adjoining Western Ghats facilitate such vast agro-biodiversity of agricultural lands of Kerala. They are rich in various tree crops of economic and dietary importance. Among the agricultural land use practices traditional homegardens constitute the principal component in terms of area and diversity. A homegarden refers to the traditional land use system around a homestead, where several species of plants are grown and maintained by the household members and their products are primarily intended for the family consumption. Homegardens are multistoried agroforestry systems that are ecologically complex as compared to other monospecific production systems. They are structurally and functionally diverse and offer multitude of outputs to the farmer. There are different types of homegardens existing around the world like homegardens of humid tropics (eg: Kerala homegardens), chagga homegardens of Tanzania, parkland systems of sub-Saharan Africa, satayoma farmlands of Japan, talun-kebun and pekarangan of Java, rung von ao ca chuong of Vietnam, etc. (Nair, 1993; Nair and Kumar, 2006; Abebe, *et al.*, 2006).

Millions of marginal farmers depend homegardens for their livelihood and nutritional security apart from array of tangible and other ecological benefits that touch their day to day life. The trees in this farmlands offer multiple functions such as food, fodder, fuel, timber, medicinal plants, pulpwood, other NTFPs, etc. (Cromwell *et al.*, 1999; Kumar, 2006). Small-scale farmers prefer homegardens because they establish a variety of low-input, low-maintenance tree crops. The diversity of crops reduces risk of crop failure for farmers.

Apart from these direct benefits, homegardens provide enumerable indirect services also. They help to enhance soil fertility, reduce soil erosion, improve water quality, enhance biodiversity, carbon sequestration, increase aesthetics etc. Nitrogen fixing trees enhances the soil fertility and improve soil physical, chemical and biological properties. Tree roots function as nutrient pumps with their deep root systems derive nutrient from deeper layers. Further, this large

network of roots conserves the nutrients and water by functioning as 'safety nets' (Suprayogo, 2000). Homegardens have large amount of total soil organic carbon than many other solo cropping systems (Saha *et al.*, 2010). They maintain soil fertility/reducing erosion via organic matter inputs to the soil, nitrogen fixation and nutrient recycling. Homegarden conserve and improve the year round availability of water through reducing runoff and increasing infiltration. Apart these benefits to humankind homegarden play vital role in conservation of biodiversity by ensuring habitat for diverse flora and fauna (Kumar *et al*, 1994; Kumar and Nair, 2004).

One of the most exciting environmental function offered by trees would be their enormous potential to sequester atmospheric carbon and thereby involving in carbon dioxide emission reduction and consequent climate change mitigation. Homegardens sequester C both in biomass and soil, reduce fossil-fuel burning by promoting wood fuel production, help in the conservation of C stocks in existing forests by alleviating the pressure on nature. India's intended nationally determined contributions (INDC) as per Paris climate agreement include reduction in the emissions intensity of its GDP by 33 to 35 per cent by 2030 from 2005 level and to create an additional carbon sink of 2.5 to 3 billion tonnes of CO_2 equivalent through additional forest and tree cover by 2030 (EARP, 2015). Government of India has already undertaken several schemes to increase the tree cover such as Green India Mission (GIM), National Afforestation Programme (NAP) Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS), Integrated Watershed Management Programme (IWMP), National Bamboo Mission (NBM) and different plans under Compensatory Afforestation Fund Management and Planning Authority (CAMPA) (FSI, 2015). State governments also are taking effort to launch such schemes such as Haritha Keralam of Kerala government and several schemes by other states. All these schemes and plans are aimed to scale up tree cover inside and outside of forest area. As the scope of expansion of tree cover in the recorded forest areas is limited, Tree Outside Forests (TOF) is the focal point for meeting countries commitments.

Homegardens are the hub of TOF in Kerala. About 80 per cent of total timber supply in Kerala is through TOF only. Homegardens are the major source of timber after rubber plantations which contribute about 35.3 % of the total timber supply in the state (Krishnankutty and Chundamannil, 2012). Average standing stock of timber in the homegardens of Kerala ranged from 6.6 to 5.8 m^3 ha^{-1} and standing fuel volume from 23 to 86 m^3 ha^{-1} (Kumar *et al.*, 1994). Almost 65 % of the domestic wood demand was met exclusively from homesteads of Kerala (Krishnankutty *et al.*, 2005). Other than timber, demand for fuel wood and fodder also increasing. In Kerala, about 82 per cent of fuel wood requirement was met from homegardens alone (Krishnankutty *et al.,* 2005). However there has been drastic reduction in the supply of wood from the homegardens of Kerala in recent times.

Accelerated changes in land use practices in Kerala have resulted in paradigm shift towards non-agricultural land use trends. The primary driver for this undesirable change could be attributed to the skewed socio-economic scenario. Furthermore, the impacts of commercialization have resulted in massive conversion of agricultural lands for other alternative uses. The traditional multitier agroforestry systems with rich tree wealth is the most affected in this shift. There has been large scale erosion in tree wealth from the traditional homegardens and farm lands of Kerala. In this changing scenario it would be important to assess the tree distribution and the diversity in homestead lands of Kerala. Knowledge about present standing stock of important timber species would be useful for taking effective actions to manage the rising demand for timber and fuel wood. Further more, an insight into the present status of homegardens in terms of their structural, functional attributes and the possible socio-economic reasons for change will give valuable information for the revitalization of tropical homegardens as a viable land use option. In this backdrop a study was undertaken to investigate the structural and functional attributes of homegardens of Thrissur district, Kerala with the following specific objectives:

- To assess the diversity, structure and standing stock of timber trees in the homegardens of Thrissur District, Kerala.
- To assess the wood qualities of the selected commercially important timber species from the homegardens of Thrissur.
- To determine the socio-economic drivers of homegarden change in the district.

REVIEW OF LITERATURE

REVIEW OF LITERATURE

2.1 HOMEGARDEN

By definition homegardens are traditional agroforestry systems and characterised by multi-story combinations of various trees, crops and sometimes in association with animal components, around the homesteads (Kumar and Nair, 2004). It has been considered as the oldest form of agriculture in Southeast Asia as well as the earliest tropical land-use management system (Wiersum, 2006). Homegardens are distributed in several regions of world like Java of Indonesia, Shamba and Chagga in East Africa, Central America, India, Bangladesh, Philippines, etc. The major parts of the country where homegardening is being practiced constitute humid, high rainfall regions like Kerala, Konkan regions, North eastern regions and Andaman and Nicobar (Nair and Kumar, 2006). They have unique features such as year round production of food and a wide range of products such as wood, firewood, fodder, spices, medicinal plants, ornamentals, etc., enhanced resource productivity over time, less chance of production failure due to presence of diverse species, potential to serve as reservoir of genetic diversity, and sturdy against pests and disease outbreaks (Cromwell *et al.*, 1999).

Traditional homegardens are low input sustenance farming systems often establishing in skewed land conditions while providing multiple outputs to meet livelihood needs of millions of people of tropics. The evolutionary trends strongly propose that homegardens are closely related to the traditions and culture of the marginal farmers. Hence, homegardens are ecologically and economically sustainable production systems that are socially acceptable. It was developed through generations of gradual intensification of farming in response to increasing population pressure and the corresponding land shortage (Kumar and Nair, 2004; Wiersum, 2006). Traditionally, the homegardens mainly produce supplementary products such as vegetables, fruits and other crops, other than the staple food crops produced on open farmlands. But with the advent of commercialization, crop preference has

been shifted to selected cash crops such as coconut (*Cocos nucifera*) or rubber (*Hevea brasiliensis*).

Sustainability of homegarden includes two main dimensions: ecological sustainability and social sustainability (Wiersum, 1995). Social sustainability got very less systematic attention (Torquebiau, 1992; Kumar and Nair, 2004). Social sustainability deals about either the social acceptability of homegardens among rural farmers or about the ability of homegardens to adjust to socioeconomic changes.

2.2 DIVERSITY IN HOMEGARDENS

Species diversity in tropical homegarden is reported to be very high due to species having different life forms, height and canopy structure (Soemarwoto and Conway, 1991). Normally, diversity is expressed as the average number of species per homegarden in a specific region. Homegardens structure over regions depends on ecological, local environmental, socioeconomic and cultural factors (Abdoellah, 1990; Kumar and Nair, 2004). Somehow homegardens simulates evergreen forests by means of the combination of diverse tree and crops organized in multi-tiered form (Chandrashekara 1995; Ewel, 1999). These homegardens have a major role in maintaining biological diversity of native and exotic species. High species diversity is the corner stone that differentiate homegarden from other agricultural land use practices (Swift and Anderson 1993; Kumar *et al.*, 1994; Abebe *et al.*, 2006). So they are often expressed as the epitome of biodiversity (Kumar and Nair, 2004). Homegardens are important genome pools and in compliance with the Convention on Biological Diversity articles 7, 8 and 10(c) (Heywood and Watson, 1995). Ninez (1987) observed that non-economic species are planted in homegardens for the reasons of taste preference, tradition, or availability of planting material. The compact species presence in the homegardens, results an almost permanent ground cover of litter. But all these species differ in their decay rates and in the rate and pattern of nutrient release (Isaac and Nair, 2006). Geographic conditions also influence homegarden component

diversity. Highland homegardens shows a lower species diversity and simpler species composition when compared to lowlands (Karyono, 1990). There is also a trend of decrease in diversity and density of woody plants with increasing age of farmlands, while diversity of woody species increase with increasing age (Tolera, *et al.*, 2008).

2.1. STRUCTURAL DIVERSITY

The high diversity and mixture of annuals and perennials at varying heights makes a convoluted horizontal and vertical structure for the homegardens. This multi-layered canopy structure is efficient in utilization of sunlight and in terms of water and soil conservation (Wiersum, 1982; Torquebiau, 1992) and which create number of niches within the homegarden. The structural combinations of crops raised in homegardens of a specific region are strongly affected by the preferences and specific needs of the farmer, besides all socioeconomic and ecological factors (Vogl *et al.*, 2002). However, such a complex multi stratification can't be seen in some homegardens like Mediterranean (Catalonia, Spain) and the arid tropical gardens (Soqotraisland, Yemen) (Agelet *et al.*, 2000).

Homegardens have a major role in in-situ conservation and maintaining genome pool for urban biodiversity because it provides a sufficient breeding bed for the diverse community of plants and animals (Gajaseni and Gajaseni, 1999; Watson and Eyzaguirre, 2002; Kehlenbeck *et al.*, 2007). Thus, multi-species and multi-storied structure is the major reason behind the homegarden's socio-economic adaptability and stability, ecological balance and sustained productivity (Peyre *et al.*, 2006). Nair and Sreedharan, 1986 observed that in the tropics and subtropics the average homegarden size ranges from 0.2 to 0.5 ha. These limited land restricting large scale intensification of agriculture. This skewed land availability in Kerala results in cultivation of numerous species with in those limited area. Homegarden are developed as a multi-storied, multi species farming system that integrates various livelihood components in a sustainable model in the most profitable

pattern (Nair, 2001). Typical Kerala homegardens have multilayer structure mostly 3-4 strata with herbaceous ground layer consisting of food crops, forage, medicinal and other crops while the middle storey overtop fruit trees and spice crops (Nair, 1993; Kumar and Nair, 2004). The upper most canopies mostly consists large timber trees and palms such as coconut, teak, mahogany, and some of the other fast growing multi-purpose trees. For example, the Andaman homegardens of India, consists 5 characteristic strata (Pandey, *et al.*, 2006). Coconut is the most prominent tree crop, then comes arecanut and spices in high rainfall regions like Kerala. The intensive crop management practices like chemical fertilization, management of palm interspaces for intercropping etc. are restricted to such economically relevant crops only (Peyre *et al.*, 2006). Coconut, arecanut, mango, jack, are the predominant tree species in the upper stratum of Kerala homegardens. The garden boundaries are demarcated by timber species like teak, mahogany, ailanthus and bamboos (Chandrashekara and Baiju 2010; Kumar and Nair, 2004).

Homegarden size is an important factor that related to species diversity (Devi and Das, 2013; Kumar and Nair, 2004). Number of studies shows an inverse relation with homegarden size species diversity. For example, in a study Kumar *et al.*, (1994) narrated that small homegardens of Kerala have higher floristic diversity (<0.4 ha size; Simpson's diversity index, D = 0.61) which decreased with increase in homegarden size i.e. medium (0.4 to 2.0 ha, D=0.44) and large (>2 ha, D = 0.46) gardens. In yet another study in central Kerala, identical trend was noticed with the total count of species as 145, 173, and 138, respectively, for the small, medium, and large sized homegardens (Kumar, 2011). Similar study from the homegardens of Mizoram, the small gardens showed highest diversity (81 species) while medium and large homegardens showed lower count with 53 and 37 respectively (Sahoo *et al.*, 2010). Efficient utilization of space can be seen in small homegardens where small scale farmers integrate more crops for their multiple requirements from their small farming premise.

Socio-economic status and livelihood circumstances may affect the species composition and pattern of the homegardens. For reason, the marginal farmers utilizes the limited land for essential staple food production instead of supplementary crop production. Urban people who have access to non-farm incomes may no longer maintain homegarden as part of their farming system, instead aesthetic preference dominate their retention. Hence, not only the overall livelihood conditions, but also some socio-economic variables such as access to off-farm labour opportunities impact the homegarden structure and composition (Wiersum, 2006)

2.2. FUNCTIONAL DIVERSITY

Nair and Kumar (2006) observed that farmers considered trees as just part of their agricultural landscapes but in homegardens they formed an important component. Homegardens are intimate assemblage of tree-crop-livestock in variable spatial and temporal sequence. Homegardens are sustainable land-use systems which are sound and efficient to fulfil the basic needs of the local populations (Fernandes and Nair, 1986; Landauer and Brazil, 1990). The homegarden possess multiple functional groups such as vegetables, medicinal plants, ornamental plants, and trees for shade, timber, fruits, nuts and resins (Kumar, 2011). In general, homegardens play a vital role in providing food, fodder, energy, shade, shelter and many other goods and services (McNeely and Schroth, 2006). Homegarden products ensure year round availability of these supplementary products for sustenance and income generation (Wiersum, 1982). The species diversity in homegarden is determined by functional priorities of farmers. This may vary with regions and geographic conditions. For example Peruvian homegardens consists more fruit trees such as *Mangifera indica L., Eryngium foetidum L., Syzygium sp., Cocos nucifera L.*, etc. (Perrault-Archambault and Coomes, 2008). A study from central Sudan also reported the preference for fruit trees. The study finds that Lime (*Citrus aurantifolia*), guava (*Psidium guajava*), mango (*Mangifera indica*),

date palm (*Phoenix dactylifera*) and grapefruit (*Citrus paradisi*) were the five most preferred species from that area (Gebauer, 2005).

A study done by Kumar (2011) reported 208 tree species from the Kerala homegardens. Among them coconut was the most prominent species. *Mangifera indica, Artocarpus heterophyllus, Tamarindus, Erythrina indica, Macaranga peltata, Thespesia populnea, Gliricidia sepium* were the other preferred tree species in Kerala homesteads (Kumar *et al.*, 1994).

Agricultural crop diversity also changes substantially in every homegarden. Preferred understorey crops of Kerala homegarden includes vegetables such as brinjal, ladies finger, cow pea; ash guard, bitter guard, snake guard, black pepper, tuber crops such as colocasia, elephant food yam, diascoria. Banana is the common intercrop in homegardens throughout Kerala (Kumar and Nair, 2004).

2.2 BENEFITS OF HOMEGARDENS

2.3.1 Food security and health

Many studies reveals homegardens as the traditional remedy for food crisis and malnutrition in many developing countries (Johnson-welch *et al.*, 2000). It is a supplementary source of food and other livelihood for marginal farmers. Homegardens are important in the aspects of contributing direct benefits such as easy and increased access to the food products. Food from homegarden include vegetables, fruits, roots, palms, spices, medicines, and animal products (Peyre *et al.*, 2006; Alam, 2011). Poor and marginal farmers depend more on homegarden for their staple food than the large scale farmers (Wiersum, 2006). As the poor farmers can't afford expensive crop products and animal products, homegardens provides a cheap resource of food items. For example, some of the traditional agroforestry systems like milpa, cacao (*Theobroma cacao*) under trees, and homegardens of the Maya community of San Jose, Belize, almost solemnly meet the family day to day needs, and contribute 62% of family income (Levasseur and Oliver, 2000).

30

Studies reveals that fruit and other food trees constitute integral part of all homegardens (Nair, 1993). Torquebiau (1992) observed that 3 per cent to 44 % of the total calorie and 4 % to 32 % of the protein intake met from homegarden supplementary products. The homegardens are also significant sources of minerals and nutrients. Studies revealed that families involved in year-round production and consumption of vitamin rich fruits and vegetables, alleviated deficiencies of iodine, vitamin A and iron (Molina *et al.*, 1993). Integration of livestock and poultry to the homegarden further enriches the dietary availability as animal nutrients such as milk, egg, meat, etc. and this may be the main or only source of animal protein available for the farmers (de la Cerda and Mukul, 2008).

Medicinal plants are an important constituent of homegardens, next only to food crops and fruit trees. Indiscriminate extraction of medicinal plants over years endangered the existence of some of these valuable species and reduced their supplies also. Homegardens can satisfy both production and in situ conservation of medicinal plants to ensure sufficient supplies and to avoid threat of extinction from natural sources (Rao and Rao, 2006). They were used as medicine for humans and livestock and as biological pesticides against diseases and pest infestation of crops. In developing countries about 80% people use medicinal plants from their homegarden for treating various illness and to improve health conditions (Rao and Rao, 2006). A study found that in Kandyan homegardens of Sri Lanka, out of 125 plant species about 30% were used exclusively for medicinal purpose (Perera and Rajapakse, 1991). In case of Kerala homegardens, 25 trees and shrubs were medicinally important out of the 127 woody species (Kumar *et al.*, 1994).

2.3.2 Economic benefits

Apart from livelihood provision homegardens provide substantial economic benefits to the farmer (Ninez, 1985). They improve rural employment opportunities, living standards and income generation options of small and marginal farmers (Torquebiau, 1992). They are recognized as low

input production systems which produce high end products for the subsistence of poor farmers (Ranasinghe, 2009). Multiple outputs and less intensive management are the basic feature that distinguish traditional homegardens from other land use systems. A study from Vietnam showed that families living in mountains depends on homegarden for more than 22% of their income generation (Trinh *et al.*, 2003). For instance southeastern Nigerian farmers makes more than 60% of income from tree and animal components of their homegarden (Okigbo, 1990). Often the income generated from sale of homegarden products improve the livelihood security of the family and make betterment of social and cultural status (Wilson, 1995). Economic analysis of homegardens in Kerala suggests that intensity of economic profit (mean profit per sq. m) is higher in smaller homegardens and they constitute almost 50% of household consumption (Mohan, 2004). A study from northeast Indian homegardens denotes that sale of products was intense among the large sized homegardens which were with commercial motives and a lesser trend was observed in the medium size gardens while majority of the produce were consumed by small homegarden farmers (Sahoo *et al.*, 2010).

Trees cultivated in homegarden also contributing income to the farmers. In Bangladesh homegardens, average income generated from trees were 22,619 BDT (Bangladesh Taka) per household (Zaman *et al.*, 2010). This income is very less for marginal farmers as compared to large farmers.

2.3.3 Wood production in homegardens

In many parts of the world, homegardens still act as a production unit of wood for domestic needs. For instance some reports observe that 70 to 84 per cent of the commercial timber requirements of peninsular India met from the tropical homegardens itself (Kumar and Nair 2004) and 70 per cent of the saw logs in Bangladesh came from homesteads (Singh, 1987). Another study suggest almost 65 per cent of the domestic wood demand was met exclusively from homesteads of Kerala (Krishnankutty *et al.*, 2005). A recent study finds that Kerala homegardens contribute 35.3 % of total timber and industrial

wood supply (Krishnankutty and Chundamannil, 2012). Major share of timber supply provided by rubber estates (46.6%) and only 1.6 per cent contributed by forests of Kerala.

A detailed study based on the survey of 17 selected taluks of Kerala found that average commercial standing stock of homesteads ranged from 6.6 to 50.8 m^3 ha^{-1} and fuel wood volume ranged from 23 to 86 m^3 ha^{-1} (Kumar *et al.*, 1994). Homegardens are rich in non-timber products such as bamboo. A study on the standing stock of thorny bamboo (*Bambusa bambos* (L.) Voss) in the homegardens in three districts of Kerala, India found considerable stocking to the amount of 28,659 Mg (Thrissur), 124, 389 Mg (Palakkad), and 86, 267 Mg (Malappuram) on dry weight basis (Kumar *et al.*, 2005; Kumar, 2008). Rural households depend homegarden for most of their biofuel requirements. (Krishnankutty, 1990; Wickramasinghe, 1996; Levasseur and Olivier, 2000; Shanavas and Kumar, 2003; Kumar and Nair, 2004). For example, studies from south and Southeast Asia suggests 51% to 90% of their domestic fuelwood needs is met from homegardens alone (Krishnankutty, 1990; Torquebiau, 1992). There is no scientific studies which deals with quantity and quality of phytofuels production by homegardens and their extraction methods. Homegardens are recognized depositories of other non-timber products such as medicinal and aromatic plants, green leaf manure, ornamentals, gums, resins and chemical extractives (Rao *et al.*, 2004).

2.4 WOOD QUALITY OF TIMBER SPECIES FROM HOMEGARDEN

According to Bhat *et al.* (2005) teak wood from dry site homegardens have higher decay resistance to brown-rot fungi and are associated with higher extractive content and darker colour. Teak wood cultivated in homesteads differ from forest plantation grown timber in certain characteristics such as log form, extend of natural defects, appearance or wood colour and grain as well as natural durability depending on the dry or wet locality (Thulasidas *et al.*, 2006; Bhat *et al.*, 2004).. Teak wood from wet homegardens show less saturation of colour but no significant difference was observed between

samples of wet and dry homegardens and forest plantation with regard to brightness and redness. Despite these factors, wood density and strength properties are almost similar for all localities.

2.5 ECOSYSTEM SERVICES

The multi-storied structure and high species diversity of the homegardens help to mitigate environmental problems which are commonly related with monocultural cropping systems (Nair & Sreedharan 1986). All agroforestry systems provide numerous ecosystem services. Woody perennials helps to reduced soil erosion by providing natural cover through litter fall or pruning residues and reduce the impact of raindrops, improve soil structure, soil nitrogen content and nutrient retention enhancement (Beer *et al.*, 1998; Fassbender *et al.*, 1991). There is a significant difference in the quality and magnitude of ecosystem services provided by homegardens from those provided by all other types of agroecosystems (Calvet-Mir *et al.*, 2012). Some of the important ecosystem services performed by homegardens include maintenance of soil fertility, control of pests and pathogens, biodiversity conservation, clean water supply, carbon sequestration, maintenance of rural landscapes and rural living standards, and maintenance of recreational areas for ecotourism (Sandhu *et al.*, 2010; Swinton *et al.*, 2007; Zhang *et al.*, 2007).

The most important environmental function rendered by homegardens is their carbon sink properties and plays a major role in climate change mitigation. The unique peculiarity of homegardens among other agroforestry systems is that they perform all the three mechanisms in greenhouse gas reduction strategy *viz.* carbon sequestration, carbon substitution and carbon conservation (Montagnini and Nair, 2004; Kumar, 2006). Homegardens sequester C much better than intensively managed crop lands (Nair *et al.*, 2009). Because trees and other perennial components in the homegardens sequester substantial amount of CO_2. A study with survey of homegardens of selected 28 panchayaths of central Kerala, India estimated that aboveground carbon stocks of trees (>20cm girth at breast height) were 24.32 Mg ha^{-1}

(Kumar, 2011). Another study by Saha *et al.* (2009) in Kerala homegardens found that soil C stock was directly related to plant diversity of homegarden. Compared to monospecific production systems, homegardens has an ability to sequester C in a best cost effective way and which is lower than any other emission reduction or sequestration techniques (Kumar, 2006). A study done by Saha *et al.* (2010) compared total soil organic carbon (SOC) content in the whole soil in six different land-use systems in Thrissur district, Kerala. Among the six land use systems forest land had highest SOC (176.6 Mg ha^{-1}). Small homegardens and large homegardens had next highest SOC in the soil (119.3 6 Mg ha^{-1} and 108.2 Mg ha^{-1} respectively). Which are very high compared to coconut based monoculture land and paddy field. Trees and their deep and well distributed root system act as nutrient pumps and the fine roots dynamics furnish substantially to enhance the carbon storage and nutrient availability of the soil. Anyway there is great variation among homegardens in this regard. For example, a study in Indonesia by Roshetko *et al.* (2002) reported that soil organic carbon ranged between 10.4 to 103.7 Mg C ha^{-1} among the homegardens.

2.6 THREATS

Homegardens are undergoing extensive changes that deteriorate their intrinsic characteristics. New government policies and population pressures leads to changes in agriculture scenario and the high market-orientation do exert considerable pressures on homegardens (Kumar and Nair, 2004). Arrival of high-input- intensive agricultural practices and the substitutes for the homegarden products resulted to face serious setbacks in content and quality of these traditional systems. There are plenty of reports that deals with alarming rates of conversion of homegardens to other systems more prominently to monoculture based commercial systems (Kumar and Nair, 2004; Abdoellah *et al.*, 2006). In a study, out of 30 homegardens studied from Kerala 50% still continues traditional features, whereas 33% adopted modern practices (Peyre *et al.*, 2006). The modernization process includes a gradual

concentration on a limited number of cash crop species, a decrease of the tree/shrub diversity, an increase of ornamental plants, a gradual homogenization of homegarden structure and an increased use of external inputs. Commercialization, switched cultivation systems more specialized and rural people turned employing in non-primary production activities. This results changes in many rural farming systems in general, and homegardens in particular. Loss of 27 varieties of mango during a 60-year period reported from West Java, Indonesia (Soemarwoto, 1987) and decline in diversity due to fragmentation in Chagga homegardens of Tanzania (Rugalema, *et al.*, 1994) are examples. It has raised the question as to whether homegardens are becoming extinct (Kumar and Nair 2004). The uprising fears that the traditionally diverse and ecologically sustainable homegardens will gradually disperse into monospecific agricultural practices with undetermined sustainability (Soemarwoto, 1987).

MATERIALS AND METHODS

MATERIALS AND METHODS

3.1 MATERIALS

3.1.1 Study Area

The study on the assessment of standing stock of timber and analysis of the functional diversity of the homegardens was carried out in Thrissur district of Kerala (Fig 1).

3.1.1.1 Thrissur district

Thrissur district, the cultural capital of Kerala is situated in the central part of the state. Spanning an area of about 3,032km^2, Thrissur district is home to over 10% of Kerala's population. Thrissur is located at 10.52°N 76.21°E and has an average altitude of 2.83m. It is bounded on the north by Malappuram district and west by Arabian Sea (54 km). Descending from the heights of the western ghats in the east, the land slopes towards the west forming three distinct natural divisions- the highlands, the plains and the sea board. The Periyar, Chalakkudy, Karuvannur, Kurumali River and Bharathapuzha are the main river systems in the district. The district has a tropical humid climate with an oppressive hot season and plentiful and seasonal rainfall. Annual rainfall is about 3000 mm.

Paddy cultivation is by far the largest agricultural practice pursued by a major section of the people in Thrissur. The low lying lands are cultivated with paddy and are fit only for this purpose. The major irrigation sources in the district are the Peechi, Vazhani, Chalakkudy and Cheerakuzhi Projects. The ayacut of Peechi project which is the largest, consists of 46,000 acres of cultivable land. Next to paddy, tapioca forms the chief food crop. The coconut palm dominates the garden crops of the district. Among the condiments and spices that grow in the district, arecanut is the most important. A large variety of fruit trees are also grown in the district.

Fig1. Map of Thrissur district, Kerala

Assessment of the standing stock of wood, structural and funtional analysis of homegardens in the various panchayaths in Thrissur district was carried out following a stratified sampling procedure. The details of the selected panchayaths are given in Table 1 and their demographic features are given below.

(a) Avinissery panchayath

Avinissery panchayath is situated in Cherppu block of Thrissur taluk (Fig 2). It is located at 10.481260°N, 76.1976000°E. It has 7.82 Km^2 area and extended over Palissery and Avinissery villages. The borders of Avinissery panchayath shares with Koorkenchery, Cherppu, Ollur, Vallachira and Paralam panchayths. It falls in midland region of Thrissur. Laterite soil is the predominant soil type of this panchayath.

(b) Mundathikode

Mundathikode village is situated in Wadakkancherry block of Thalappilly taluk in Thrissur district (Fig 3). It is located at 10.63157°N, 76.189362°E. Mundathikode is surrounded by Puzhakkal, Chowannur, Thrissur and, Mullassery Taluks. It is extended over Mundathikode, Puthuruthy, Peringandoor, Minalur, and Parlikad and an area of 23.37 km^2. It is a high land region of Thrisuur district. Laterite soil is the major soil type of Mundathikode panchayath.

(c) Pananchery

Pananchery is a village in Thrissur district, located along the National Highway from Thrissur to Palakkad (Fig 4). Peechi, Pattikad, Kannara are located in Pananchery. The Kerala Forest Research Institute, the popular tourist spot of Peechi Dam and the Kerala Engineering Research Institute are located in Pananchery. Pananchery panchayath is located at 10.556°N, 76.308°E. It is extended over Pananchery and Peechi villages and an area of 141.71 km^2. It is a highland region of Thrissur district and laterite soil is its major soil type.

(d) Kaipamangalam

Kaipamangalam is situated in Mathilakam block of Kodungallur taluk (Fig 5). It is located 10°19′0″N, 76°8′0″E. Kaipamangalam assembly segment consist of

Fig 2. Map of Avinissery panchayath

Fig 3. Map of Mundathikode panchayath

Fig 4. Map of Pananchery panchayath

Fig 5.Map of Kaipamangalam panchayath

Edavilangu, Edathiruthy, Eriyad, Kaipamangalam, Mathilakam, Perinjanam and Sreenarayanapuram Panchayats in Kodungallor Taluk. It is a coastal region of Thrissur district and sandy loam is the major soil type.

(e)Orumanayur

Orumanayur is situated in Chavakkad block of Chavakkad taluk (Fig 6). It islocated at 10°33′30″N, 76°2′5″E and an area of 5.19 km^2. It is fall under coastal region of Thrissur district and sandy loam is the major soil type.

(f) Chelakkara

Chelakkara panchayath is situated in Pazhayanoor block of Thalappilly taluk (Fig 7). Chelakara is located at 10.70°N 76.35°E. It is extended over Chelakkara, Venganellur, Thonnurkara, Kurumala, and Pulakode villages and has an area of 59.83 km^2. It falls in high land region of Thrissur district. The major soil type found here is laterite soil.

(g) Chazhur

Chazhur panchayath is located in Anthikkad block of Thrissur taluk (Fig 8). It is located at 10.4451800°N, 76.136970°E. It is extended over Pullu. Alappad, Chazur, Kurumpilavu and Inchamudi villages and an area of 25.54 km^2. It is geographically a midland region. Laterite is the major soil type of this panchayath.

(h) Mala

Mala panchayath situated in Mala block of Mukundapuram taluk (Fig 9). It is located in 10.7160099°N, 76.3050726°E. It is extended over Kuruvilassery, North Vadama and Annalloor villages and has an area of 28.35 km^2. It is a midland region of Thrissur district. Laterite soil is the major soil type of this panchayath.

Fig 6. Map of Orumanayur panchayath

Fig 7. Map of Chelakkara panchayath

Fig 8. Map of Chazhur panchayath

Fig 9. Map of Mala panchayath

Table 1. Selected panchayaths and peri-urban area for the study in the district

Region	Panchayath	Block	Taluk	No. of homegarden		
				small	medium	large
High land	Chelakara	Pazhayanoor	Thalappilly	10	10	10
	Mundathikode	Wadakkancherry	Thalappilly	10	10	10
	Pananchery	Ollukkara	Thrissur	10	10	10
	Panjal	Pazhayanoor	Thalappilly	10	10	10
Mid land	Avinissery	Cherpu	Thrissur	10	10	10
	Chazhur	Anthikkad	Thrissur	10	10	10
	Mala	Mala	Mukundapuram	10	10	10
	Vellangallur	Vellangallur	Mukundapuram	10	10	10
Coastal region	Kaipamangalam	Mathilakam	Kodungallur	10	10	10
	Orumanayur	Chavakkad	Chavakkad	10	10	10
Peri-urban region	Chalakkudy	Chalakkudy	Mukundapuram	10	10	10
Total				**330**		

94

(i) Panjal

Panjal panchayath is situated in Pazhayanoor block of Thalappilly taluk (Fig 10). It is located at 32.55°N, 74.58°E. It is extended over Painkulam, Panjal and Killimangaalm villages and an area of 30.39 km^2. It is a highland area and having laterite soil as the major soil type.

(j) Vellangallur

Vellangallur panchayath is situated in Vellangallur block of Mukundapuram taluk (Fig 11). It is extended over Vallivattom, Thekkumkara, Karumathra and Vadakkumkara. It is located at 10.3013°N 76.2160°E. It is fall under midland region of Thrissur district. Laterite soil is the major soil type of Vellangallur panchayath.

(k) Chalakkudy

Chalakkudy municipality is situated in Chalakkudy block of Mukundapuram taluk (Fig 12). It is located at 10.30°N, 76.33°E. It can be considered as a peri-urban area and laterite is the major soil type.

3.2 METHODOLOGY

The methodology involved a two-stage stratified random sampling scheme in which the entire Thrissur district was divided into three topographic regions *viz.* highland, midland and coastal region. From each of these three regions 10 % of panchayaths were randomly selected for the study.

3.2.1 Selection of panchayaths

The total number of the selected panchayaths were 10 (ie, 10% of total 99 panchayaths of Thrissur district). Panchayaths were selected from each topographical divisions proportional to their size. Accordingly out of the total ten panchayaths four, three and three were randomly selected belonging to highland, midland and coastal regions respectively. Additionally, one municipal region was

Fig 10. Map of Panjal panchayath

Fig 11. Map of Vellangallur panchayath

Fig 12. Map of Chalakkudy municipality

randomly selected as a representative of the peri-urban region. Hence the total survey location were 11 (ten panchayaths + one peri-urban region).

3.2.2 Selection of homegarden

From these 11 survey localities 30 homesteads were randomly selected such that the total number of homesteads to be surveyed were 330. The homegardens were further grouped based on holding size into three classes *viz.* small (< 0.2 ha), medium (0.2-0.4 ha) and large (> 0.4 ha). The 30 homegardens from each locality has been selected in such a way that 10 each belong to these three size classes. The details of the farmers were collected from the respective panchayath offices. From this list of homegardens for each panchayath 30 households were randomly selected such that 10 homegardens each belonged to small, medium and large farmer groups.

3.2.3 Homegarden survey

The survey of selected homegardens were divided into two parts. The first part was a socio-economic survey and other one was enumeration survey of trees and crops.

3.2.3.1 Socio-economic survey

The socio-economic survey conducted based on a structured questionnaire (Appendix I). Various quantitative and qualitative information of the farmers were collected through this questionnaire survey. Information related to economic inflow and outflow within the homegarden, managerial aspects, past and present trend in homegardening, etc. were collected. The surveyed homegardens were subjected to detailed socio-economic analysis based on size of homegarden. The various parameters *viz*; source of income, input cost to homegarden, output from homegarden, cash flow, dependence on homegarden for livelihood, returns from each of the homegarden products, etc. were quantified and analysed.

3.2.3.2 Tree enumeration

All trees and agricultural crops in the selected homegarden were surveyed and recorded. Height and DBH of all the trees were measured and recorded. Height of the trees were measured using Laser Vertex Hypsometer. The DBH of the trees were measured using measuring tape. The standing volume of the timber tree species were computed following standard equations. The trees enumerated were grouped into various functional groups *viz*; timber species, fruit species, fodder species, fuel species, green manure, medicinal species, ornamental species and other use categories. The standing volume was then computed separately for each of the functional groups. The tree enumeration data pertaining to the selected 10 panchayaths and one peri-urban region were extrapolated to the entire Thrissur district following appropriate statistical techniques.

3.2.3.3 Wood quality assessment

Wood quality of the timber trees were assessed through Non-Destructive Techniques (NDT) using a Pilodyn and Tree Sonic Microsecond timer (Dhanya, 2012).

a. Pilodyn

Pilodyn is an instrument widely used in the field conditions to assess wood density. A flat nosed, spring loaded pin of 2.5 mm diameter is the important part of this instrument. Firing the pin into the wood by loaded spring will make the pin pierce into the wood. The depth of penetration of the pin can be observed from the scale in the instrument. The pilodyn penetration is an indirect method for assessing tree basic density. The penetration depth is negatively correlated with basic density. The pin of pilodyn was inserted on each of the standing timber species main trunk and three readings were taken from a single tree. Mean of these were taken as final pilodyn penetration depth (ppd). To calculate oven dry Specific Gravity ($SP_{o.d}$) for each species separate regression equations developed by Dhanya (2012) was used. The equations used are given below.

Plate. 1 A typical Kerala homegarden

Plate. 2 Interaction with farmer as part of socio- economic survey

Plate. 3 Livestock components in a typical Kerala homegarden

Plate 4. Agricultural components and tree components in a typical Kerala homegarden

Teak $Y = -34.2 X + 35.17$

Jack wood $Y = -51.13 X + 43.46$

Mahogany $Y = -92.85 X + 59.53$

Where Y is mean ppd of each species and X is the oven dry Specific Gravity ($SP_{o.d}$).

b. Treesonic Microsecond Timer (TMT)

Treesonic Microsecond Timer is designed to measure stress wave propagation time in trees in the fibre direction. The signal is generated by a hammer tap on the start sensor. By measuring the distance between the two sensors, velocity in fibre direction can be calculated. Fibre direction velocity correlates well with elastic modulus and strength of wood. In this way wood material of the tree can be graded before cutting.

To measure stress wave propagation time the start transducer was placed on trunk of standing tree. The stop transducer was placed 1 m apart opposite bottom side of the trunk. The start transducer was hit with hammer to induce stress waves. The time required for the sound waves to pass from the start transducer to stop transducer through the log was read out from the timer. Three readings were taken from a single tree and mean of the reading was taken as the final reading. Stress wave velocity was calculated by dividing the distance travelled by the time taken. Dynamic Modulus of Elasticity (MOE_{dyn}) was determined by the relationship: $E = \rho \times v^2$, where E is the MOE_{dyn}, ρ is the density at the time of measurement in kg m^{-3} and v is the velocity in m s^{-1}.

3.2.3.4 Agricultural crop enumeration

Agricultural crops cultivated inside the homegardens were recorded. Number or area occupied by each agricultural crops such as plantation crops like coconut, arecanut, nutmeg rubber and vegetables like amorphophallus, ginger, turmeric,

56

Plate 5 Various field activities using on stsnding trees, a) Tree height measurment using Laser Vertex Hypsometer in homegarden, b) Tree DBH measurment using measuring tape in homegarden, c) Pilodyn measurments in timber trees of homegarden, d) Treesonic Microsecond Timer.

spinach, etc. were measured. Using these details diversity of crops in each size category of homegardens were assessed.

3.2.3.5 Assessment of abundance of tree species

Abundance of different tree species was projected to the Thrissur district by following standard methods. Total number of each species in each panchayath was calculated from the collected field data. Abundance per ha of homegardens was computed by dividing the total number of each species by total area of homegardens surveyed from the respective panchayath. Then average of abundance per ha for different sampled panchayaths were assessed. It was then converted to district level by multiplying the average per ha number with total geographical area of Thrissur district (excluding wetlands, forest lands and uncultivable lands).

3.2.3.6 Standing stock assessment

Standing stock of different tree species of selected homegardens of Thrissur district was calculated by using basic volume equation. The equation used for the standing stock calculation of standing trees is shown below.

Volume = $(G^2/4\pi)*F*H$. Here, 'G' is the girth at breast height (GBH), 'F' is the form factor and 'H' is the height of the tree. The general form factor value of 0.65 was considered for volume computation.

Total standing stock of each species in each panchayath was calculated from the collected field data by using standard equation. Standing stock of different tree species projected to the Thrissur district was assessed by following standard methods. Standing stock per ha of homegardens obtained from dividing the total standing stock of each species by total area of homegardens surveyed from the respective panchayath. Then average of these standing stock per ha for all panchayaths were assessed. This was converted to district level by multiplying the average per ha standing stock with the geographical area under homegardens of Thrissur district.

58

3.2.3.7 Diversity indices

To calculate tree and agricultural diversity, diversity indices used were,

1. Simpson index of diversity, $1 - \lambda = 1 - \{\sum \frac{ni(ni-1)}{N(N-1)}\}$ Where, λ= Simpson index, n_i = number of individuals or amount of each species (i.e., the number of individuals of the i^{th}species) and N = total number of individuals for the site
2. Shannon Wiener Index, $H' = \sum[(\frac{n}{N}) \times \ln(\frac{n}{N})]$ Where, ni = number of individuals or amount of each species (the ithspecies), N = total number of individuals (or amount) for the site, and ln = the natural log of the number

59

RESULTS

RESULT

4.1 TREE DIVERSITY

4.1.1 Total species diversity

Total species identified from the selected 330 homegardens of Thrissur district was 163 which includes both tree species and agricultural crops (Table 2). Agricultural crops constitutes both understorey crops and plantation crops. Total species diversity was highest in large homegardens (135) followed by medium and small homegardens. There were total 122 tree species and 41 agricultural crop species recorded from total selected 330 homegardens. Both trees and agricultural species diversity were also followed the trend of total species diversity. Tree species and agricultural crop species were highest in large homegardens and least in small homegardens.

Table 2. Total species diversity in selected 330 homegardens of Thrissur district, Kerala

	Trees	Agricultural crops		Total
		Understorey crops	Plantation crops	
Small	85	28	3	116
Medium	95	29	3	128
Large	102	29	4	135
Total number of species excluding overlapping	**122**	**41**		**163**

Table 3 shows the total diversity of tree species among various size classes of the selected homegardens of Thrissur district. Overall 122 tree species were encountered in the homegardens across the various eco-regions in Thrissur district. Among the size categories, large homegardens accounted 102 tree species which was around 83.6 % of total tree species encountered. This was followed by 95 species in the medium homegardens and the lowest diversity of 85 species was recorded from the small homegardens.

61

Among the various selected eco-regions homegardens in the midland region represented the highest species diversity (83 species) followed by highland (75 species), coastal land (66 species) and lowest in the peri-urban area (53 species) (Table 4). The proportional share of highland, midland, coastal land and peri-urban area to the total tree diversity were 62.3 %, 68 %, 54.1 % and 43.4 % respectively. Among all the eco-regions peri-urban area registered the lowest species diversity.

Table 3. Total number of tree species present in three size categories of homegardens of selected panchayaths of Thrissur district

Size class	Number of species	Percentage of total species
Small	85	69.7
Medium	95	77.9
Large	102	83.6
Total tree diversity excluding overlapping species across three size classes =122		

Table 4. Total number of tree species present in all eco-regions of homegardens of selected panchayaths of Thrissur district, Kerala

Eco-region	Number of species	Percentage of total species
Highland	76	62.3
Midland	83	68
Coastal land	66	54.1
Peri-urban area	53	43.4
Total tree diversity excluding overlapping species =122		

Diversity indices for the total 122 tree species identified from selected panchayaths of Thrissur district are shown in Table 5. Shannon diversity index of total trees identified from the selected panchayaths was 3.43 and Simpson diversity index was 0.93. Small homegarden had the least Shannon Diversity Index with 3.34 whereas large homegardens showed highest Shannon Index of

62

3.47. Medium homegardens displayed a modest figure of 3.36. Simpson index of diversity did not show appreciable variation among all three size classes. Large homegarden had highest Simpson Diversity Index with 0.94 while other two size classes showed only marginal difference (0.93).

Table 5. Diversity indices of total tree species in households of varying sizes in selected panchayaths of Thrissur district, Kerala

Size class	Shannon Wiener Index	Simpson Diversity Index
Small	3.34	0.93
Medium	3.36	0.93
Large	3.47	0.94
Total	3.43	0.93

4.1.2 Functional diversity

Functional diversity of various tree species in the selected homegardens of Thrissur district are given in Table 6. Timber species accounted highest in tree diversity (53 species) which accounted 43.4 % of the total trees species identified. Fruit trees also registered higher diversity (39 species) as compared to other species. Other prominent groups with fair diversity include fuel trees (33 species), fodder trees (23 species) medicinal (18 species) and ornamental trees (16 species) and other use trees (15 species). Green manure trees registered the lowest species diversity (13 species).

Functional diversity among three size classes of selected homegardens of Thrissur district showed narrow variations (Table 7). Among all functional groups timber trees registered highest diversity with higher value in medium homegardens (47 species). However, fruit species, the next highest in diversity had major share in large homegardens (39 species). Small and medium homegardens recorded similar number of timber species, 41 and 42 respectively. Interestingly, fruit tree diversity was fairly high in all the homegarden types with upper edge in medium sized homegardens (37 species). Green manure trees again

63

represented the lowest diversity, with less variation across size classes. In general, most of the functional groups had higher number of species in large homegardens. But fruit trees, medicinal trees and ornamental trees were higher in medium homegardens. All functional groups registered lowest number of species in small homegardens.

Table 6. Tree species diversity across in each functional groups of trees from selected homegardens of Thrissur district, Kerala

Functional group	Number of species	Percentage of total species
Timber	53	43.4
Fruit trees	39	32
Fodder trees	23	18.8
Fuel trees	33	27
Green manure	13	10.6
Medicinal trees	18	14.8
Ornamental trees	16	13.1
Other use trees	15	12.3
Total tree diversity excluding overlapping of species =122		

Table 7. Functional diversity across varying size class of homegardens of Thrissur district, Kerala

Functional groups	Number of species		
	Small	Medium	Large
Timber	41	42	47
Fruit	32	37	32
Fodder	16	18	19
Fuel	21	23	26
Green manure	11	11	13
Medicinal	14	14	17
Ornamental	12	14	13
Other use	7	7	12
Total tree diversity excluding overlapping of species across functional groups			
	85	**95**	**102**

64

Recorded species of different functional groups also compared between different eco-regions and peri-urban area (Table 8). There was considerable species overlapping among different functional group in the study. Total number of woody species in the various eco-regions (excluding overlapping species) were 76, 83, 66 and 53 for highland, midland, coastal land and peri-urban region respectively. Timber trees were the dominant functional group of all regions. Higher number of timber tree species were found from highland region (47). Lowest number was in peri-urban area (27). Fruit trees constituted the next major functional group within the eco-regions. There was a minimal variation in number of fruit tree species between highland and midland regions, 47 and 46 respectively. Similar to timber trees, the coastal and peri-urban area homegardens represented lowest share of fuel wood species. Fodder trees, fuel trees and green manure trees also showed the same trend as timber trees. Highland and midland had the equal number of species while peri-urban had the lowest number of species. Except ornamental trees and medicinal trees all the other functional groups indicated lowest number of species in peri-urban area.

Table 8. Functional diversity of the homegardens among selected eco-regions of Thrissur district, Kerala

Functional group	Number of species			
	Highland	Midland	Coastal land	Peri-urban area
Timber	47	46	36	27
Fruit	31	34	34	27
Fodder	19	19	14	10
Fuel wood	24	24	18	10
Green manure	12	12	10	7
Medicinal	16	16	11	14
Ornamental	13	15	11	12
Other use	8	10	7	4
Total tree diversity excluding overlapping species across functional groups				
	76	**83**	**66**	**53**

65

Table 9 gives better understanding of tree species diversity in Thrissur district. It gives detailed description of variation in tree species diversity among size classes within each eco-regions. Timber trees were the dominant functional group among size classes of all eco-regions. In highland region the highest number of timber tree species recorded from large homesteads (39). Higher number of timber trees were found in large homegardens of midland (38). However, timber tree species were higher in the small homegardens for coastal land and peri-urban regions respectively. Fruit tree species registered equal number in all size classes of homesteads of highland region (26). In midland and coastal land medium homegardens registered higher number of fruit species (30 and 28 respectively). But in peri-urban area all size classes shared more or less similar number of fruit tree species. Green manure trees and other use trees were the least diverse functional groups in all size classes of four regions.

4.1.3 Total tree diversity of selected panchayaths

Table 10 provides the panchayath-wise information on the tree species diversity in the homegardens of Thrissur district. The total tree diversity in the Thrissur district was 122. Highest diversity was recorded from Panjal panchayath located in highland region. Difference was not prominent among other panchayaths in highland region. Mala represented marginally higher number of species among the midland panchayaths. Interestingly, coastal panchayaths Orumanayur (49) and Kaipamangalam registered the lowest species diversity. Invariably, the peri-urban homegardens showed lower diversity.

4.2 ABUNDANCE PER HECTARE OF TIMBER TREE SPECIES OF THRISSUR DISTRICT

Table 11 shows abundance per hectare and projected number of important timber tree species in Thrissur district. Table also provide the total number per hectare of timber species in Thrissur district (42 no/ha) and projected number of all timber species (62,44,770). Clearly *Mangifera indica* topped in terms of abundance and total number in Thrissur district. It had 11 number per

66

Table 9. Number of species of trees from varying size categories of different eco-regions of Thrissur district, Kerala

Functional groups	High land				Midland				Coastal				Peri-urban			
	S	M	L	T	S	M	L	T	S	M	L	T	S	M	L	T
Timber	31	36	39	47	30	35	38	46	19	27	27	34	19	18	17	27
Fruit trees	26	26	26	31	24	30	28	34	26	28	26	36	19	20	20	27
Fodder	13	14	14	19	11	14	15	19	7	11	12	14	9	7	7	10
Fuel	16	20	22	24	18	22	21	28	9	14	14	19	12	11	9	14
Green manure	8	10	10	12	9	11	11	12	6	9	9	10	6	5	6	7
Medicinal	10	13	14	16	11	12	15	16	10	9	10	11	7	4	3	14
Ornamental	8	11	10	13	11	13	10	15	3	7	7	11	7	8	8	12
Other use	4	6	7	8	6	4	9	10	2	4	4	7	3	2	3	4

S- Small homegardens, M- Medium homegardens, L- Large homegardens, T- Total

hectare of individuals present in whole Thrissur district. The projected number of *Mangifera indica* in Thrissur district was 15,98,849. *Tectona grandis* and *Artocarpus heterophyllus* had almost similar abundance of 6 and 7 per ha respectively. The projected abundance of *Tectona grandis* and *Artocarpus heterophyllus* in Thrissur district were 8,67,272 and 9,63,928 respectively. The corresponding standing number of trees for *Swietenia macrophylla* and *Ailanthus triphysa* in Thrissur district were 344171 and 105234 respectively.

Table 10. Total number of species present in each selected panchayaths of Thrissur district, Kerala

Panchayath	Eco-region	No of species	Percentage of total species
Mundathikode	Highland	63	51.6%
Pananchery	Highland	65	53.3%
Panjal	Highland	72	59%
Chelakkara	Highland	65	53.3%
Avinissery	Midland	66	54.1%
Mala	Midland	67	54.9%
Chazhur	Midland	63	51.6%
Vellangallur	Midland	65	53.3%
Orumanayur	Coastal land	49	40.2%
Kaipamangalam	Coastal land	58	47.5%
Chalakkudy	Peri-urban	60	49.2%
Total tree diversity excluding overlapping species =122			

Table 11. Abundance per hectare and estimated number of important timber tree species of Thrissur district, Kerala

Species	Number per ha		Estimated number in Thrissur district	
	Mean	SE	Mean	SE
Mangifera indica	11	1.01	1598849	149587.3
Tectona grandis	6	0.61	867272	90674.1
Artocarpus heterophyllus	7	0.57	963928	84813.6
Artocarpus hirsutus	2	1.03	345648	152296.8
Swietenia macrophylla	2	0.77	344171	113207.9
Ailanthus triphysa	1	0.11	105234	16363.2

68

4.2.1 **Abundance of tree species in all three eco-regions and peri-urban area**

4.2.1.1 ***Abundance of timber species***

Among the various timber tree species, *Mangifera indica* showed the largest abundance in the homegardens across eco-regions and size classes (Table 12). Total abundance of *Mangifera indica* in the highland was 438 (out of total of 120 selected homegardens in highland). Abundance of *Mangifera indica* was similar for large and medium homegardens in highland region (173 and 172 respectively), while a sharp drop in abundance of small homegardens (93) has been observed. Abundance of *Mangifera indica* in the midland were comparable with that in highland. For instance, the total number in 120 sampled homegarden was 417 for highland. Large homegardens invariably showed higher number (166; total of 40 homegardens). Coastal region probably showed higher abundance as compared to other regions. For instance, total abundance of *Mangifera indica* was 303 (from 60 homegardens) as against the total values of 438 and 417 from 120 homegardens from highland and midland regions.

Tectona grandis was one of the most important timber species of homegardens. In highland and midland regions *Tectona grandis* showed highest abundance in large homegardens (out of total 120 homegardens). Teak registered 148 individuals in large homesteads of highland region (out of 40 homegardens), while in midland it was 163. Coastal area exhibited dominance of teak in medium homesteads (35 nos) from total of 20 selected homesteads in medium category of coastal land. Another prominent species found in homegardens of Thrissur district was *Artocarpus heterophyllus*. Even though the selected homegardens were less in coastal region, number of *Artocarpus hirsutus* was luxurious. For instance, the total number of *A. hirsutus* from 60 homegardens was 128 while the corresponding number from 120 homegardens was 80 and 44 for midland and highland respectively.

4.2.1.2 ***Abundance of fruit tree species***

Variety of fruit trees also were observed in surveyed homesteads (Table 13). Among the fruit trees *Mangifera indica* showed clear abundance for all eco-regions. *Artocarpus heterophyllus* and *Artocarpus hirsutus* were the other two major preferred fruit trees in homegardens. *Artocarpus heterophyllus* had almost similar abundance in large (105) and medium (103) homesteads of highland region (total of 40 selected homegardens each). Interestingly, *Artocarpus heterophyllus* displayed an unusual trend in midland region. In general, small homegardens showed lesser abundance for most of tree species. However in midland region *Artocarpus heterophyllus* had least abundance in medium homegardens (83), while, large homesteads had highest abundance (141) and small homesteads had next highest abundance (121. *Anacardium occidentale, Tamarindus indica, Artocarpus altilis*, *Garcinia gummi-gutta,* etc. were the other important fruit trees found from the homegardens studied.

4.2.1.3 ***Abundance of fodder species***

Mangifera indica and *Artocarpus heterophyllus* were the two dominant fodder species found from all eco-regions (Table 14). *Macaranga peltata* was identified as one of the important fodder species of all eco-regions. Highland region had a total of 130 individuals of *Macaranga peltata* (from a total of 120 homegardens). Large homegardens of highland showed higher abundance with 60 individuals. Medium homegardens of highland registered 51 individuals of *Macaranga peltata*. However, midland region had a variation in this trend. It had higher abundance of *Macaranga peltata* in medium homesteads (66) instead large (63). In contrast, it was completely absent in coastal area. Large homesteads of all regions possess higher number of this species. *Gliricidia sepium* present in all regions. In highland it was more in medium homegardens. But in midland and peri-urban area it was highest in large homesteads.

4.2.1.4 ***Abundance of fuel species***

Important fuel species found from homegardens of different eco-regions are given in Table 15. *Tamarindus indica* was one of the important fuel species found in all eco-regions. It was found higher in large homesteads of every regions. From highland region 77 individuals of *Tamarindus indica* were recorded, while 42 numbers were from large homesteads. Midland listed total 77 individuals and 44 were from large homesteads. However, tamarindus had poor representation from coastal and peri-urban region. In peri-urban area out of 24 individuals 12 were from large homesteads.

4.2.1.5 ***Abundance of green manure species***

Multipurpose trees like *Macaranga peltata, Gliricidia sepium, Azadirachta indica, Cassia fistula, Garuga pinnata, Phyllanthus emblica, Terminalia catappa* were the major green manure tree species of surveyed homegardens from all regions (Table 16). *Azadirachta indica* was a common green manure species which has almost similar distribution in all size classes of every regions.

4.2.1.6 ***Abundance of medicinal plant species***

Medicinal plants constituted one of the integral functional group in the homegardens studied. *Azadirachta indica* was the most common medicinal tree species enlisted from all regions (Table 17). It registered more or less similar number of individuals in large and medium homegardens of every regions. *Strychnos nux-vomica, Cinnamomum zeylanicum, Hydnocarpus pentandra, Phyllanthus emblica* were the other important medicinal trees observed from the various eco-regions.

4.2.1.7 ***Abundance of ornamental tree species***

Cassia fistula was the predominant ornamental tree species found from all regions (Table 18). Recorded individuals of *Cassia fistula* in highland region was 29 individuals. Large and medium homegardens registered similar number of individuals (11 and 12 respectively). Large homesteads of midland had 18 number

71

of individuals whereas small and medium homegardens had same number (12). Medium households of peri-urban area showed a large difference in number of individuals from small and large households. But the domination of ornamental trees were higher in the peri-urban region. For instance, a total of 30 homegardens in the peri-urban region gave 28 cassia tree while, a total from 120 homegardens in midland region was only 42 trees. *Polyalthia longifolia* identified as another important ornamental tree present in all regions. All other observed ornamental tree species like *Mimusops elengi*, *Michelia champaca*, *Bauhinia acuminata*, *Diospyros buxifolia*, *Cananga odorata*, *Bauhinia purpurea*, *Plumeria rubra*, *Araucaria heterophylla*, etc. showed less representation in all regions.

4.2.2 Abundance of functional groups of trees based on size of holding

Most of the important timber species were found recorded in the large homesteads of selected panchayaths of Thrissur district (Table 19). *Mangifera indica* was the prominent timber species of all size categories. Large homesteads had highest number of individuals (506) followed by medium (449) and small homesteads (278). *Tectona grandis* also had the highest number of individuals in large homesteads (372). Small households listed a few numbers of teak compared to other two size categories. All other timber species such as *Artocarpus heterophyllus, Swietenia macrophylla, Artocarpus hirsutus, Acacia mangium, Dalbergia latifolia, Acacia auriculiformis, Ailanthus triphysa,* etc. were also registered more number of individuals in large homegardens compared to medium and small homegardens.

As seen before *Mangifera indica, Artocarpus heterophyllus* dominated the fruit trees in the selected homegardens (Table 20). *Artocarpus hirsutus,* yet another important fruit tree found highest in large homesteads (135). However, lesser was its abundance in small and medium homegardens. Other fruit tree species were relatively less in the homegardens though the larger gardens giving higher distribution.

Table 12. Abundance of important timber species in varying sizes of homegarden from three eco-regions and one peri-urban area of Thrissur district, Kerala

Species	High land (Total of 40 homegardens per each size holds)				Midland (Total of 40 homegardens per each size holds)				Coastal (Total of 20 homegardens per each size holds)				Peri-urban (Total of 10 homegardens per each size holds)			
	S	**M**	**L**	**T**	**S**	**M**	**L**	**T**	**S**	**M**	**L**	**T**	**S**	**M**	**L**	**T**
Mangifera indica	93	172	173	438	96	155	166	417	71	98	134	303	18	24	33	75
Tectona grandis	23	81	148	252	45	91	163	299	12	35	24	71	13	13	37	63
Artocarpus heterophyllus	54	103	105	262	121	83	141	345	14	33	45	92	19	18	16	53
Swietenia macrophylla	2	17	34	53	16	26	52	94	4	11	74	89	3	8	11	22
Artocarpus hirsutus	0	20	24	44	13	18	49	80	32	43	53	128	4	6	9	19
Acacia mangium	0	5	7	12	1	2	4	7	0	3	8	11	0	0	0	0
Dalbergia latifolia	2	3	5	10	0	0	9	9	2	1	1	4	0	0	3	3
Acacia auriculiformis	0	1	1	2	0	1	0	1	0	0	1	1	0	0	0	0
Ailanthus triphysa	1	7	21	29	5	12	16	33	1	3	4	8	1	6	5	12

Table 13. Abundance of important fruit tree species in varying sizes of homegardens from three eco-region and one peri-urban area of Thrissur district

Species	High land (Total of 40 homegardens per each size holds)				Midland (Total of 40 homegardens per each size holds)				Coastal (Total of 20 homegardens per each size holds)				Peri-urban (Total of 10 homegardens per each size holds)			
	S	**M**	**L**	**T**	**S**	**M**	**L**	**T**	**S**	**M**	**L**	**T**	**S**	**M**	**L**	**T**
Mangifera indica	93	172	173	438	96	155	166	417	71	98	134	303	18	24	33	75
Artocarpus heterophyllus	54	103	105	262	121	83	141	345	14	33	45	92	19	18	16	53
Artocarpus hirsutus	0	20	24	44	13	18	49	80	32	43	53	128	4	6	9	19
Anacardium occidentale	2	34	31	67	14	29	54	97	8	5	16	29	4	8	10	22
Tamarindus indica	6	29	42	77	19	24	44	87	0	5	5	10	4	8	12	24
Artocarpus altilis	0	4	11	15	7	10	9	26	4	4	5	13	2	0	4	6
Garcinia gummi-gutta	4	12	11	27	17	15	24	56	7	7	14	28	8	5	9	22

Table 14. Abundance of important fodder species in varying sizes of homegardens from three eco-region and one peri-urban area of Thrissur district

Species	High land (Total of 40 homegardens per each size holds)				Midland (Total of 40 homegardens per each size holds)				Coastal (Total of 20 homegardens per each size holds)				Peri-urban (Total of 10 homegardens per each size holds)			
	S	**M**	**L**	**T**	**S**	**M**	**L**	**T**	**S**	**M**	**L**	**T**	**S**	**M**	**L**	**T**
Mangifera indica	93	172	173	438	96	155	166	417	71	98	134	303	18	24	33	75
Artocarpus heterophyllus	54	103	105	262	121	83	141	345	14	33	45	92	19	18	16	53
Macaranga peltata	19	51	60	130	11	66	63	140	0	0	0	0	6	0	11	17
Artocarpus hirsutus	0	20	24	44	13	18	35	66	32	43	53	128	4	6	9	19
Tamarindus indica	6	29	42	77	19	24	44	87	0	5	5	10	4	8	12	24
Gliricidia sepium	16	23	16	55	22	28	34	84	2	4	4	10	8	11	15	34
Garuga pinnata	0	2	4	6	6	6	22	34	0	2	2	4	0	0	0	0
Leucaena leucocephala	0	3	4	7	6	0	4	10	1	1	0	2	1	0	0	1
Syzygium cumini	2	9	9	20	2	2	5	9	2	7	6	15	1	2	0	3
Phyllanthus emblica	3	5	4	12	5	7	10	22	2	2	2	6	2	3	0	5

Table 15. Abundance of important fuel species in varying sizes of homegardens from three eco-region and one peri-urban area of Thrissur district

Species	High land (Total of 40 homegardens per each size holds)				Midland (Total of 40 homegardens per each size holds)				Coastal (Total of 20 homegardens per each size holds)				Peri-urban (Total of 10 homegardens per each size holds)			
	S	**M**	**L**	**T**	**S**	**M**	**L**	**T**	**S**	**M**	**L**	**T**	**S**	**M**	**L**	**T**
Mangifera indica	93	172	173	438	96	155	166	417	71	98	134	303	18	24	33	75
Macaranga peltata	19	51	60	130	11	66	63	140	0	0	0	0	6	0	11	17
Anacardium occidentale	2	34	31	67	14	29	42	85	8	5	16	29	4	8	10	22
Tamarindus indica	6	29	42	77	19	24	44	87	0	5	5	10	4	8	12	24
Gliricidia sepium	16	23	16	55	22	28	34	84	2	4	4	10	8	11	15	34
Azadirachta indica	6	22	21	49	16	19	17	52	6	5	9	20	7	6	6	19
Cassia fistula	6	12	11	29	12	12	18	42	2	5	4	11	6	14	8	28
Garuga pinnata	0	2	4	6	6	6	22	34	0	2	2	4	0	0	0	0
Terminalia catappa	1	3	6	10	1	1	5	7	0	2	6	8	0	1	2	3

Table 16. Abundance of important green manure species in varying sizes of homegardens from three eco-region and one peri-urban area of Thrissur district

Species	High land (Total of 40 homegardens per each size holds)				Midland (Total of 40 homegardens per each size holds)				Coastal (Total of 20 homegardens per each size holds)				Peri-urban (Total of 10 homegardens per each size holds)			
	S	**M**	**L**	**T**	**S**	**M**	**L**	**T**	**S**	**M**	**L**	**T**	**S**	**M**	**L**	**T**
Mangifera indica	93	172	173	438	96	155	166	417	71	98	134	303	18	24	33	75
Macaranga peltata	19	51	60	130	11	66	63	140	0	0	0	0	6	0	11	17
Gliricidia sepium	16	23	16	55	22	28	34	84	2	4	4	10	8	11	15	34
Azadirachta indica	6	22	21	49	16	19	17	52	6	5	9	20	7	6	6	19
Cassia fistula	6	12	11	29	12	12	18	42	2	5	4	11	6	14	8	28
Garuga pinnata	0	2	4	6	6	6	22	34	0	2	2	4	0	0	0	0
Phyllanthus emblica	3	5	4	12	5	7	10	22	2	2	2	6	2	3	0	5
Terminalia catappa	1	3	6	10	1	1	5	7	0	2	6	8	0	1	2	3

Table 17. Abundance of important medicinal plant species varying sizes of homegardens from three eco-region and one peri-urban area of Thrissur district

Species	High land (Total of 40 homegardens per each size holds)				Midland (Total of 40 homegardens per each size holds)				Coastal (Total of 20 homegardens per each size holds)				Peri-urban (Total of 10 homegardens per each size holds)			
	S	**M**	**L**	**T**	**S**	**M**	**L**	**T**	**S**	**M**	**L**	**T**	**S**	**M**	**L**	**T**
Azadirachta indica	6	22	21	49	16	19	17	52	6	5	9	20	7	6	6	19
Annona squamosa	10	5	6	21	9	7	7	23	2	1	1	4	3	5	3	11
Strychnos nux-vomica	2	8	11	21	5	10	23	38	0	0	0	0	5	0	0	5
Cinnamomum zeylanicum	0	3	5	8	6	3	6	15	3	7	4	14	2	0	0	2
Phyllanthus emblica	3	5	4	12	5	7	10	22	2	2	2	6	2	3	0	5
Aegle marmelos	1	4	10	15	3	11	6	20	2	0	1	3	1	0	0	1
Simarouba glauca	2	2	5	9	1	2	8	11	3	1	3	6	0	0	2	2

Table 18. Abundance of important ornamental tree species in varying sizes of homegardens from three eco-region and one peri-urban area of Thrissur district

Species	High land (Total of 40 homegardens per each size holds)				Midland (Total of 40 homegardens per each size holds)				Coastal (Total of 20 homegardens per each size holds)				Peri-urban (Total of 10 homegardens per each size holds)			
	S	**M**	**L**	**T**	**S**	**M**	**L**	**T**	**S**	**M**	**L**	**T**	**S**	**M**	**L**	**T**
Cassia fistula	6	12	11	29	12	12	18	42	2	5	4	11	6	14	8	28
Polyalthia longifolia	2	1	18	21	4	8	9	21	0	0	4	4	4	7	4	15
Mimusops elengi	0	1	1	2	3	7	11	21	4	5	1	10	1	2	6	9
Michelia champaca	2	2	5	9	6	7	2	15	0	2	0	2	3	2	0	5
Bauhinia acuminata	1	0	2	3	4	4	5	13	0	0	0	0	2	2	1	5
Diospyros buxifolia	4	2	1	7	1	5	0	6	0	2	0	2	3	2	0	5
Cananga odorata	0	4	3	7	4	2	2	8	0	2	1	3	0	0	1	1
Bauhinia purpurea	2	1	1	4	6	1	3	10	0	0	0	0	2	0	2	4
Plumeria rubra	3	3	1	7	1	3	2	6	0	0	2	2	0	0	1	1
Araucaria heterophylla	2	0	0	2	2	0	4	6	0	1	2	3	0	0	2	2

Table 19. Abundance of important timber species from homegardens of selected panchayaths of Thrissur district based on size of holding

Species	No of individuals (Total of 110 homegardens)		
	Small	Medium	Large
Mangifera indica	278	449	506
Artocarpus heterophyllus	208	237	307
Tectona grandis	93	220	372
Swietenia macrophylla	25	62	171
Artocarpus hirsutus	49	87	135
Acacia mangium	1	10	19
Dalbergia latifolia	4	4	18
Acacia auriculiformis	0	2	2
Ailanthus triphysa	8	28	46

Table 20. Abundance of important fruit species from homegardens of selected panchayaths based on size of holding

Species	No of individuals (Total of 110 homegardens)		
	Small	Medium	Large
Mangifera indica	278	449	506
Artocarpus heterophyllus	208	237	307
Artocarpus hirsutus	49	87	135
Anacardium occidentale	28	76	111
Tamarindus indica	29	66	103
Artocarpus altilis	13	18	29
Garcinia gummi-gutta	36	39	58

Mangifera indica and *Artocarpus heterophyllus* were the two abundant fodder trees from all three size classes (Table 21). *Macaranga peltata* was the next important fodder species. It had more stocking in large homesteads (134) followed by medium homegardens (117) while small homesteads showed very poor stocking (36). *Artocarpus hirsutus, Tamarindus indica, Gliricidia sepium,* etc. showed only spare dominance.

80

Table 21. Abundance of important fodder species from homegardens of selected panchayaths based on size of holding

Species	No of individuals (Total of 110 homegardens)		
	Small	Medium	Large
Mangifera indica	278	449	506
Artocarpus heterophyllus	208	237	307
Macaranga peltata	36	117	134
Artocarpus hirsutus	49	87	135
Tamarindus indica	29	66	103
Gliricidia sepium	48	66	69
Garuga pinnata	6	10	28
Leucaena leucocephala	8	4	8
Syzygium cumini	7	20	20

Major fuel species observed in all three size categories include *Mangifera indica, Macaranga peltata, Anacardium occidentale, Tamarindus indica, Gliricidia* and *sepium* (Table 22). *Tamarindus indica* was one of the multipurpose tree used as a fuel wood also. Apart from these, tamarind showed fairly good stocking in large homegardens while it was poorly seen in the other categories of homegardens. Other fuel wood species were *Azadirachta indica, Cassia fistula, Garuga pinnata, Terminalia catappa,* etc.

Table 22. Abundance of important fuel species from homegardens of selected panchayaths based on size of holding

Species	No of individuals (Total of 110 homegardens)		
	Small	Medium	Large
Mangifera indica	278	449	506
Macaranga peltata	36	117	134
Anacardium occidentale	28	76	111
Tamarindus indica	29	66	103
Gliricidia sepium	48	66	69
Azadirachta indica	35	52	53
Cassia fistula	26	43	41
Garuga pinnata	6	10	28
Terminalia catappa	2	7	19

81

Most of the green manure tree species were recorded more in large homegardens (Table 23). *Mangifera indica* and *Macaranga peltata* were the two prominent green manure trees found in all size classes of selected homegardens of Thrissur district. *Gliricidia sepium* was one of the most favoured green manure tree species. It counted 69 individuals in large homegardens while 66 in medium and 48 in small homegardens. Yet another important species *Garuga pinnata* registered 28 number of individuals in large homegardens, 10 from medium and 6 from small homegardens.

Table 23. Abundance of important green manure species from homegardens of selected panchayaths based on size of holding

Species	No of individuals (Total of 110 homegardens)		
	Small	Medium	Large
Mangifera indica	278	449	506
Macaranga peltata	36	117	134
Gliricidia sepium	48	66	69
Azadirachta indica	35	52	53
Cassia fistula	26	43	41
Garuga pinnata	6	10	28
Phyllanthus emblica	12	17	16
Terminalia catappa	2	7	19

Predominant medicinal species identified from selected homesteads were *Azadirachta indica, Aegle marmelos, Annona squamosa, Cinnamomum zeylanicum, Strychnos nux-vomica,* etc. Most common medicinal tree observed was *Azadirachta indica.* It had almost equal number of individuals present in large and medium homegardens (53 and 52 respectively). *Annona squamosa* was a common fruit tree present in every size categories of homegardens. Its demand was high in the recent times as it possess some medicinal values. But it had large number of individuals in small (24), followed by medium (18) and large (17) homesteads

Table 25 listed some of the important ornamental trees found from homegardens of selected panchayaths. *Cassia fistula, Polyalthia longifolia* and

82

Mimusops elengi were the prominent species among the ornamental tree species. Other ornamental species showed only marginal presence in the various homegardens studied.

Table 24. Abundance of important medicinal tree species from homegardens of selected panchayaths based on size of holding

Species	No of individuals (Total of 110 homegardens)		
	Small	Medium	Large
Azadirachta indica	35	52	53
Annona squamosa	24	18	17
Strychnos nux-vomica	12	18	34
Cinnamomum zeylanicum	11	13	15
Phyllanthus emblica	12	17	16
Aegle marmelos	7	15	17
Simarouba glauca	6	5	18

Table 25. Abundance of important ornamental tree species from homegardens of selected panchayaths based on size of holding

Species	No of individuals (Total of 110 homegardens)		
	Small	Medium	Large
Cassia fistula	26	43	41
Polyalthia longifolia	10	16	35
Mimusops elengi	8	15	19
Michelia champaca	11	13	7
Bauhinia acuminata	7	6	8
Diospyros buxifolia	8	11	1
Cananga odorata	4	8	7
Bauhinia purpurea	10	2	6

4.2.3. **Abundance per hectare of functional groups**

Trends were different when the stocking was represented on per hectare basis. For example, in case of timber species *Mangifera indica* showed more abundance

in the coastal region (16 trees per ha) as compared to other regions (Table 26). *Tectona grandis* had an even distribution ranging from 4 to 7 trees per ha. *Swietenia macrophylla* and *Artocarpus hirsutus* also showed better count in the coastal region when computed on per ha basis.

Mangifera indica and *Artocarpus heterophyllus,* were the major fruit trees in the Thrissur district (Table 27). *Mangifera indica* represented the dominant fruit tree among all eco-regions. *Artocarpus heterophyllus* was the second highest in abundance, which showed highest in midland homesteads (8 trees/ha). It was relatively lower in coastal and peri-urban region. *Artocarpus hirsutus, Tamarindus indica, Anacardium occidentale, Averrhoa bilimbi,* etc. were the other common fruit trees listed from all regions, however they were not promising in number across the homegardens.

Table 26. Abundance per hectare of important timber species of different eco-regions of Thrissur district

Species	No of individuals per hectare			
	Highland	Midland	Coastal	Peri-urban
Mangifera indica	10	10	16	7
Tectona grandis	6	7	4	6
Artocarpus heterophyllus	6	8	5	5
Swietenia macrophylla	1	2	5	2
Artocarpus hirsutus	1	2	7	2
Ailanthus triphysa	1	1	0	1

Mangifera indica and *Artocarpus heterophyllus* were the two abundant fodder trees from all four regions (Table 28). *Gliricidia sepium* was the next important fodder species. In coastal area number of individuals per hectare identified were negligible. *Macaranga peltata* considered as an important green manure species found equally in highland and midland regions (3).

84

Table 27. Abundance per hectare of important fruit trees of different eco-regions of Thrissur district

Species	No of individuals per hectare			
	Highland	Midland	Coastal	Peri-urban
Mangifera indica	10	10	16	7
Artocarpus heterophyllus	6	8	5	5
Artocarpus hirsutus	1	2	7	2
Tamarindus indica	2	2	0	2
Anacardium occidentale	2	2	1	2
Averrhoa bilimbi	1	2	1	2
Garcinia gummi-gutta	1	1	1	2
Psidium guajava	1	1	1	1
Moringa oleifera	1	1	0	1

Table 28. Abundance per hectare of important fodder trees of different eco-regions of Thrissur district

Species	No of individuals per hectare			
	Highland	Midland	Coastal	Peri-urban
Mangifera indica	10	10	16	7
Artocarpus heterophyllus	6	8	5	5
Artocarpus hirsutus	1	2	7	2
Tamarindus indica	2	2	0	2
Anacardium occidentale	2	2	1	2
Gliricidia sepium	1	2	0	3
Macaranga peltata	3	3	0	2

Tamarindus indica, Gliricidia sepium, Macaranga peltata, etc. were some of the important fuel species other than *Mangifera indica, Artocarpus heterophyllus* and *Artocarpus hirsutus* (Table 29). Except for *Mangifera indica* and *Artocarpus heterophyllus* all the remaining fuel wood species were lesser in number.

Mangifera indica was dominant among green manure tree species (Table 30). *Tamarindus indica, Gliricidia sepium* and *Macaranga peltata* were the most common green manure tree species found in all regions. All these species were

85

preferred for other uses also. So most of the green manure species were listed in other functional groups.

Table 29. Abundance per hectare of important fuel trees of different eco-regions of Thrissur district

Species	No of individuals per hectare			
	Highland	Midland	Coastal	Peri-urban
Mangifera indica	10	10	16	7
Artocarpus heterophyllus	6	8	5	5
Artocarpus hirsutus	1	2	7	2
Tamarindus indica	2	2	0	2
Gliricidia sepium	1	2	0	3
Macaranga peltata	3	3	0	2

Table 30. Abundance per hectare of important green manure trees of different eco-regions of Thrissur district

Species	No of individuals per hectare			
	Highland	Midland	Coastal	Peri-urban
Mangifera indica	10	10	16	7
Tamarindus indica	2	2	1	2
Gliricidia sepium	1	2	0	3
Macaranga peltata	3	3	0	2
Azadirachta indica	1	1	1	2
Cassia fistula	1	1	0	2

4.2.4 Average number of trees in different eco-regions and peri-urban area

Table 31 shows the average number of important timber tree species per homegarden for various size categories for highland region. As observed earlier *Mangifera indica* dominated among the timber species with higher average number in medium and large homegardens (5) while lower value of 3 numbers in small homegardens. The maximum number of mango trees in homegarden was highest in medium homegardens (19). *Tectona grandis* showed lesser number in

the small and medium homegardens in the highland region (average 2-3 per homegarden). However large homegardens recorded fair number with an average value of 5 per homegarden while a maximum value of 17 per homegardens. The status of *Artocarpus heterophyllus* was modest in the various homegardens in the highland region with an average number of 2-3 across size classes. However the maximum number of 9 and 7 were observed for medium and large homegardens respectively. *Swietenia macrophylla* and *Artocarpus hirsutus* had marginal presence in the various homegardens in the highland region.

Timber tree abundance in the midland also showed similar trend with that of highland region (Table 32). For instance, the average number of *Mangifera indica* per homegarden was 2, 3 and 3 numbers for small medium and large homegardens respectively. Medium sized homegarden however recorded highest number of 16 mango trees from single homegarden. *Tectona grandis* also showed modest presence with 2-3 number per homegarden. However, homegarden in the large size category recorded a maximum number of 24 teak trees.

Table 31. Range and average number of individuals of important timber species from varying size classes of homegardens of highland region of Thrissur district

Species	Highland								
	Small			Medium			Large		
	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max
Mangifera indica	3	1	8	5	1	19	5	1	14
Tectona grandis	2	1	3	3	1	9	5	1	17
Artocarpus heterophyllus	2	1	4	3	1	9	3	1	7
Swietenia macrophylla	2	2	2	2	1	4	2	1	6
Artocarpus hirsutus	0	----	----	2	1	3	2	1	3

67

Despite the lower average number of *Artocarpus heterophyllus* per homegarden, the maximum number was observed from the homegarden belonging to smaller size category (24) where the corresponding figures for medium and large homegardens were 8 and 11 respectively. *Swietenia macrophylla* showed similar status across homegardens in midland region with average number of three trees per garden.

Table 32. Range and average number of individuals of important timber species from varying size classes of homegardens of midland region of Thrissur district.

Species	Midland								
	Small			Medium			Large		
	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max
Mangifera indica	2	1	6	3	1	16	3	1	12
Tectona grandis	2	1	5	3	1	19	3	1	24
Artocarpus heterophyllus	2	1	26	2	1	8	3	1	11
Swietenia macrophylla	3	1	5	3	1	6	3	1	6
Artocarpus hirsutus	1	1	2	2	1	5	2	1	5

Table 33. Range and average number of individuals of important timber species from varying size classes of homegardens of coastal land region of Thrissur district

Species	Coastal land								
	Small			Medium			Large		
	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max
Mangifera indica	4	1	9	5	1	12	7	1	18
Tectona grandis	2	1	4	4	1	9	3	1	6
Artocarpus heterophyllus	2	1	5	2	1	4	3	1	7
Swietenia macrophylla	1	1	1	3	1	6	9	3	29
Artocarpus hirsutus	3	1	6	4	1	8	5	1	9

88

Coastal land exhibited an increase in average number of individuals of *Mangifera indica* with increase in homegarden size (Table 33). The average number of individuals were 4, 5 and 7 for small, medium and large homegardens in the coastal region. The highest number of mango trees in homegardens of coastal region reported from one large homegarden with 18 trees followed by 12 mango from yet another homegarden. The status of *Tectona grandis* in the homegardens belonging to coastal region was similar to highland with average value per homegarden ranging from 3-5. Interestingly, there was considerable increase in *Swietenia macrophylla* stocking in large homegardens with average number varied from minimum 3 to maximum 29 per homegarden. *Artocarpus hirsutus* also showed fair dominance in the large homegardens (average 5 per homegarden).

Mangifera indica showed a lower number in peri-urban homegardens as compared highland and midland regions with values ranging from 2-3 trees per homegarden (Table 34). Teak presence was lower in the small and medium gardens (average 3) while the status was marginally better in large homegardens with an average number of 5 per garden and reported a maximum of 12 number.

Table 34. Range and average number of individuals of important timber species from varying size classes of homegardens of peri-urban region of Thrissur district

Species	Peri-urban area								
	Small			Medium			Large		
	Avg	Min	Max	Avg	Min	Max	Avg	Min	Max
Mangifera indica	2	1	4	3	1	4	3	1	6
Tectona grandis	3	1	4	3	1	6	5	1	12
Artocarpus heterophyllus	2	1	3	2	1	3	2	1	3
Swietenia macrophylla	1	1	1	2	1	2	3	1	3
Artocarpus hirsutus	1	1	2	1	1	3	2	1	5

4.3 STRUCTURE OF HOMEGARDENS

Species present in three prominent layers of homegardens of selected panchayaths of Thrissur district exhibited interesting observations (Table 35). Trees, agricultural crops and medicinal plants were the prominent constituents of different layers of homegardens. Highest number of species were observed from large homegardens (139 nos) followed by medium homegardens (131 nos) and least in small homegardens (117 nos). Middle storey of all three size classes displayed higher number of species. Large homegardens showed higher number of species in all three layers. Upper storey of small homegardens had 27 species while, medium homegardens had 31 (23.66% of total species identified from small homegardens) and large homegardens had 35 species (25.18%) present in the upper storey. Middle storey of large homesteads recorded 69 species represented among the three layers. The middle storey of medium homegardens (50.38%) also showed high diversity. Even the lowest species counted in the middle storey of small homestead (58), was higher than species present in upper storey and under storey of large homegardens. Highest understorey diversity was observed in large homegardens. But all three size holdings did not show a notable difference between understorey diversity.

Table 35. Vertical stratification of trees and agricultural crop species among various categories of homegardens of Thrissur district

Vertical stories	No of species					
	Small		Medium		Large	
	No	%	No	%	No	%
Upper storey	27	23.08	31	23.66	35	25.18
Middle storey	58	49.57	66	50.38	69	49.64
Under storey	32	27.35	34	25.95	35	25.18
Total	117	100.00	131	100.00	139	100.00

4.4 STANDING STOCK OF TIMBER SPECIES

4.4.1. Standing stock per hectare of timber species in Thrissur district

Table 36 shows estimated standing stock per hectare and projected standing stock of important timber tree species in Thrissur district. From the figures it is clear that *Mangifera indica* was the leading species in terms of standing stock. It had 12.76 m^3 ha^{-1} standing stock in whole Thrissur district. The projected standing stock of *Mangifera indica* in Thrissur district was 18,84,356.3 m^3. *Tectona grandis* and *Artocarpus heterophyllus* had closer figures though lesser than mango. Standing stock per hectare of *Tectona grandis* was 10.65 m^3 ha^{-1} while *Artocarpus heterophyllus* had 10 m^3 ha^{-1}. The projected standing stock of *Tectona grandis* and *Artocarpus heterophyllus* were 15,71,871.9 m^3 and 14,77,224.5 m^3 respectively. *Swietenia macrophylla* showed considerably lower stocking with 3.14 m^3 ha^{-1} of standing stock in Thrissur district. Its standing stock projected to Thrissur district was 10,74,404.1 m^3. Standing stock per hectare of total timber species identified in Thrissur district was 55.12 m^3 ha^{-1} and projected standing stock of all timber species was 81,38,931.6 m^3.

Table 36. Standing stock per hectare and estimated volume of different timber species of Thrissur district

Species	Standing stock per ha (m^3 ha^{-1})		Projected standing stock in Thrissur district (m^3)	
	Mean	SE	Mean	SE
Mangifera indica	12.76	1.75	1884356.3	258913.3
Tectona grandis	10.65	2.16	1571871.9	319134.8
Artocarpus heterophyllus	10.00	1.60	1477224.5	235523.1
Artocarpus hirsutus	7.28	2.31	463905.6	111224.8
Swietenia macrophylla	3.14	0.75	1074404.1	341237.4
Acacia mangium	0.14	0.06	20804.7	8711.7
Dalbergia latifolia	0.14	0.03	20406.1	4748.6
Acacia auriculiformis	0.03	0.01	4429.7	2198.6
Ailanthus triphysa	1.31	0.35	193695.1	51707.7

91

4.4.2 Standing stock per hectare of timber species in different eco-regions of Thrissur district

Standing stock per hectare of important timber species varied among different eco-regions (Table 37). *Mangifera indica* was the most dominant species of all regions. Midland exhibited higher standing stock of *Mangifera indica* (14.9 m^3 ha^{-1}) followed by highland (13.6 m^3 ha^{-1}), peri-urban (10.4 m^3 ha^{-1}) and coastal area (8.8 m^3 ha^{-1}). *Tectona grandis* also shared higher standing stock in midland region (13.9 m^3 ha^{-1}), which was followed by peri-urban area (12.4 m^3 ha^{-1}), highland (11.9 m^3 ha^{-1}) and lowest in the coastal land (1.9 m^3 ha^{-1}). Estimated standing stock per hectare of *Artocarpus heterophyllus* also had the same trend as that of *Mangifera indica.* It recorded higher standing stock in midland region (12.4 m^3 ha^{-1}) followed by highland (11.3 m^3 ha^{-1}), peri-urban area (6.8 m^3 ha^{-1}) and coastal land (5 m^3 ha^{-1}). The trends were however, variable for *Artocarpus hirsutus* with high standing stock observed in coastal land (11.2 m^3 ha^{-1}) and least observed in peri-urban area (4.6 m^3 ha^{-1}). Highland had highest amount of standing stock per hectare of total timber species identified from Thrissur district (63.3 m^3 ha^{-1}) followed by midland (61.4 m^3 ha^{-1}), peri-urban region (47.6 m^3 ha^{-1}) and coastal land (m^3 ha^{-1}).

Table 37. Standing stock per hectare of important timber trees in different eco-regions of Thrissur district

Species	Standing stock per hectare (m^3 ha^{-1})			
	Highland	Midland	Coastal land	Peri-urban
Mangifera indica	13.6	14.9	8.8	10.4
Tectona grandis	11.9	13.9	1.9	12.4
Artocarpus heterophyllus	11.3	12.4	5.0	6.8
Artocarpus hirsutus	8.4	4.9	11.2	4.6
Swietenia macrophylla	3.4	3.5	1.8	3.3
Dalbergia latifolia	0.1	0.1	0.1	0.3
Ailanthus triphysa	1.8	1.2	0.3	2.1
Acacia mangium	0.2	0.1	0.2	0.0
Acacia auriculiformis	0.0	0.1	0.0	0.0

92

4.4.3. Standing stock per hectare of timber species in varying size classes of homegardens of Thrissur district

Standing stock of timber species vary according to the size categories of homegardens of Thrissur district (Table 38). Most of the species found to have major share of standing stock in medium homesteads. *Mangifera indica* displayed higher standing stock in large homesteads (15.7 m^3 ha^{-1}). Surprisingly medium and small homesteads had equal amount of standing stock (11.8 m^3 ha^{-1}). Mango had highest standing stock in small homegardens. *Tectona grandis* had higher standing stock in large homesteads (12.5 m^3 ha^{-1}). It was 10.6 m^3 ha^{-1} in medium homesteads and 6.6 m^3 ha^{-1} in small homesteads. Yet another timber species of demand was *Artocarpus heterophyllus* which had highest standing stock per ha in large homegardens (14.6 m^3 ha^{-1}). Least was found in small homegardens (7.8 m^3 ha^{-1}). Other important timber species identified from the homegardens displayed moderate standing stock in each size categories of homegardens. Highest share of standing stock of all timber species identified from Thrissur district was in medium homegardens (63 m^3 ha^{-1}). Large gardens registered moderate share of standing stock (55.2 m^3 ha^{-1}) and small gardens had the least (46.4 m^3 ha^{-1}).

Table 38. Standing stock per hectare of important timber trees in varying size classes of Thrissur district

Species	Standing stock per hectare (m^3 ha^{-1})		
	Small	Medium	Large
Mangifera indica	11.8	11.8	15.7
Tectona grandis	6.6	10.6	12.5
Artocarpus heterophyllus	7.8	12.5	14.6
Artocarpus hirsutus	3.5	10.0	6.8
Swietenia macrophylla	1.9	3.6	3.3
Dalbergia latifolia	0.1	0.1	0.2
Ailanthus triphysa	0.5	1.2	1.7
Acacia mangium	0.0	0.1	0.2
Acacia auriculiformis	0.0	0.1	0.0

93

4.5 AGRICULTURE CROP DIVERSITY

Table 39 shows average number of major agricultural crops among different size classes of homegardens of Thrissur district. Banana (*Musa sps.* AAB (Palayankodan)) was the predominant agricultural crop in all the size categories (35 in small, 74 in medium and 108 in large) followed by arecanut (*Areca catechu)*, coconut (*Cocos nucifera),* colocasia (*Colocasia esculenta),* cassava *(Manihot esculenta)* and elephant foot yam *(Amorphophallus paeoniifolius).* Coconut was only third dominant agricultural crop in selected homegardens. Interestingly, arecanut showed dominance over coconut in every size classes of homegardens. Colocasia, cassava and elephant foot yam were other dominant crops which were cultivated in the understorey of homegardens. Cassava didn't show appreciable variation across homegardens.

Table 39. Abundance of major agricultural crop species in households of varying sizes in selected panchayaths of Thrissur district, Kerala.

Species Name	Average number of individuals per homegarden		
	Small	Medium	Large
Musa sps. AAB (Palayankodan)	35	74	108
Areca catechu	21	46	73
Cocos nucifera	18	35	66
Colocasia esculenta	23	27	34
Manihot esculenta	17	18	20
Amorphophallus paeoniifolius	14	19	24

Out of 41 total species identified, diversity indices were analysed for 35 species (Table 40). Because other six species were estimated in terms of their area of extend in homegardens. All three size categories showed more or less similar number of taxa. Also a total of 2358 individuals were registered from all three

94

size categories. Large homegardens accounted the highest population with 880 individuals while small had lesser value (713). Dominance was more in small gardens as compared to other two categories. Dominance of small homegarden was 0.071 while large homegarden had a less value with 0.0593. Species diversity indices like Shannon Wiener index (H) and Simpson diversity index (1-D) were more for large households and lesser for small households.

Table 40. Diversity indices of major agricultural crop species in households of varying sizes in selected panchayaths of Thrissur district, Kerala

Diversity indices	Small (110 homegardens)	Medium (110 homegardens)	Large (110 homegardens)	Total (330 homegardens)
Number of Taxa (S)	31	32	33	35
Total no. of Individuals	713	765	880	2358
Dominance (D)	0.0711	0.0692	0.0593	0.0654
Shannon Wiener index (H)	2.92	2.96	3.08	3.01
Simpson Diversity index (1-D)	0.93	0.93	0.94	0.93

Table 41. Comparison of Shannon Diversity (H) of major agricultural crop species among varying size holds in selected panchayaths of Thrissur district, Kerala.

Groups	t-value	p-value
Small vs Medium	0.861^{ns}	0.389
Small vs large	3.714**	0.0002
Medium vs Large	2.919**	0.005

** significant at 1 % level; ns non-significant at 5 % level

95

Agricultural crops diversity showed significant difference across different size holds (Table 41). Shannon diversity index of small and medium homegardens had a t-value of 0.861 which however was not significant. But 'H' had a significant difference between small vs medium and small vs large homegardens. It had a t-value of 3.714 at small vs large comparison which was significant at 1 % level. Medium vs large had a t-value of 2.919 and it was also significant at 0.01 level.

Table 42. Abundance of major agricultural crop species among three eco-regions and one peri-urban area of Thrissur district, Kerala.

Species Name	Number of individuals per homegarden			
	High Land	Midland	Coastal	Peri-urban
Musa sps. AAB (Palayankodan)	70	83	64	78
Areca catechu	60	47	37	19
Cocos nucifera	40	34	55	32
Manihot esculenta	16	20	23	13
Colocasia esculenta	27	14	14	11
Amorphophallus paeoniifolius	28	45	28	11

Abundance of major agricultural species per homegarden among three eco-regions and a peri-urban area were shown in Table 42. This comparison based on eco-regions also showed banana as the predominant species among all four regions. Midland represented highest number of banana (83) and coastal land had the least (64) as compared to other regions. However, *Areca catechu* showed highest abundance in highland region while coconut showed dominance in coastal area with an average of 55 palms per garden. Least abundance was found in peri-urban area. In general, all cops except banana exhibited sharp decline in peri-urban area.

96

Table 43. Diversity indices of major agricultural species of three eco-regions and one peri-urban area of Thrissur district, Kerala.

Diversity	High Land	Mid land	Coastal land	Peri-urban
Taxa (S)	33	35	29	29
Total no. of Individuals	749	937	415	257
Dominance (D)	0.07226	0.06287	0.07151	0.05616
Shannon Wiener index (H)	2.946	3.023	2.919	3.091
Simpson index (1-D)	0.9277	0.9371	0.9285	0.9438

Diversity indices and dominance of different agricultural crops among three eco-regions and one peri-urban area are listed above (Table 43). There was marginal difference in the number of taxa recorded across eco-regions. In general midland had more taxa (35 speceis) while coastal region showed lowest (29 speceis). Total number of individuals per homegarden also was higher in midland (937) followed by highland (749), coastal (415) and lowest in the peri- urban area (257). Dominance was more for highland area (0.072) which was less for peri-urban area (0.056). Despite low diversity and abundance, both Shannon Wiener index and Simpson index were higher for peri-urban area.

Among the two diversity indices tested, Shannon diversity index of different eco-regions were compared (Table 44). Comparison between midland vs highland, midland vs peri-urban area and highland vs coastal area were non-significant and had t-values of 1.869, 0.553 and 0.463 respectively while midland vs coastal area, highland vs peri-urban area and coastal area vs peri-urban area comparisons were significant at 0.05 level.

Table 45 and Table 46 show area under cultivation of different agricultural crops in homegardens. These constitute the spread of six prominent agricultural crops estimated out of 41 identified agricultural crops from the selected

homegardens. *Zingiber officinale* recorded 7.48 m^2/acre area of extension across selected homegardens of various eco-regions. Highest extend of this crop was observed in medium homesteads of midland region (17 m^2/acre). Interestingly, *Amaranthus dubius* cultivated more in small homesteads of coastal land (22.26 m^2/acre).

Table 44. Comparison of Shannon Diversity index of major agricultural species of three eco-regions and one peri-urban area of Thrissur district, Kerala

Groups	t-value	p-value
Mid land vs Highland	1.869^{ns}	0.062
Mid land vs Coastal	2.383*	0.017
Mid land vs Peri-urban	0.594^{ns}	0.553
Highland vs coastal	0.735^{ns}	0.463
Highland vs Peri-urban	1.988*	0.047
Coastal vs Peri-urban	2.440*	0.015

*significant at 5% level; ns: non-significant at 0.05 level

Table 46 shows the spread of *Hevea brasiliensis* in selected homegardens of Thrissur district. *Hevea brasiliensis* was the crop with largest coverage in terms of area (756.65 m^2/acre). Also, *Hevea brasiliensis* was present only in large homesteads of every eco-region and totally absent in coastal land. Large homesteads of highland region occupy largest extend of *Hevea brasiliensis* (2918.79 m^2/acre). It was followed by peri-urban area (911.36 m^2/acre) and midland region (330 m^2/acre).

98

Table 45. Total area per acre (m^2 per acre) of the different agricultural crop species in varying size classes of homegardens of each eco-region

Eco-region	Size of households	Area/acre of each species (m^2/acre)				
		Zingiber officinale	*Curcuma longa*	*Amaranthus dubius*	*Plectranthus rotundifolius*	*Maranta arundinacea*
High land	Small	4.99	1.42	7.12	2.85	0.00
	Medium	4.99	4.99	3.63	3.18	0.00
	Large	3.11	1.36	1.85	0.58	0.19
Mid land	Small	9.26	7.33	10.03	1.54	0.00
	Medium	17.00	15.36	5.32	6.14	0.41
	Large	12.27	3.30	4.74	4.64	0.00
Coastal land	Small	10.77	7.18	22.26	7.18	0.00
	Medium	4.71	1.57	8.49	4.71	0.00
	Large	1.23	0.00	8.01	0.00	0.92
Peri-urban	Small	8.69	0.00	10.86	0.00	0.00
	Medium	7.23	6.51	0.72	0.00	0.00
	Large	2.73	1.37	6.38	4.56	0.00
Total	Small	7.86	4.55	11.31	3.03	0.00
	Medium	9.38	8.01	5.05	4.26	0.14
	Large	6.34	1.93	4.13	2.40	0.20
Grand total per acre		**7.48**	**4.15**	**5.52**	**3.05**	**0.15**

Table 46. Total area per acre (m^2 per acre) of the *Hevea brasiliensis* in homegardens of each eco-region of Thrissur district, Kerala

Eco-region	*Hevea brasiliensis*
High land	2918.79
Midland	330.00
Coastal land	0.00
Peri-urban area	911.36
Grand total per acre	**756.65**

4.6 SOCIO ECONOMIC ANALYSIS OF SURVEYED HOUSEHOLDS

An attempt was made in the present study to investigate the socio-economic condition of the homegardens and their possible reflection in the maintenance of the homegardens. The salient observations are explained hereunder.

4.6.1 Occupation

Table 47 clearly shows the occupational status of the home gardeners. General perception among the 330 homegardens surveyed suggest that aged pensioners run the homegardens (22.7%). About 20 % of the homegardeners were agriculturist and considered it as a productive asset. There were changes in occupational status of homegardens based on holding size. Almost 22.8 % of small homegardeners were pensioners while 18.2 % involved in other business activities and 15.4 % in agriculture. Other occupational areas in the small holder sector were, government employment (13.6%), private entrepreneurship (3.6%), daily wagers were more in the small holder categories (16.4%) compared to medium and large homegardens. Homegardeners' occupational status in the medium homegardens were similar with pensioners having major share (25.5%) which those were involved in agriculture was less (20.9%). Fairly high proportion of homegardens involved in business (16.4) in the medium sized homegardens. Interestingly, daily wagers occupied only less than 10% in medium and large homegardens.

100

Contrary to assumption large homegardener showed more interest in agriculture and tree farming (22.7%). This was followed by pensioners (21.8%). About 17.3 % of homegardeners in the large farmer group were involved in government jobs, while daily wagers were less than 10 %.

Eco-region wise analysis of occupation status in the selected homegardens also gave similar results are seen before (Table 48). Pensioners dominated in the homegardens in the highland, midland and peri-urban region (average 20-28.3%). Interestingly, among the surveyed homegardens, those from the coastal regions had more people involvement in agriculture (26.7%) while peri-urban region represented the lowest. Members of the household involved in daily wage occupation were more in peri-urban (20%) followed by high land (15%), coastal land (15%) and mid land (14.2%), Homegardeners in the government sector were more in the high land (19.2%) while the lowest was in the coastal region (3.3%). Interestingly, people involved in oversees jobs were more in the coastal region.

Table 49 clearly demonstrated that agriculture was the major source of income (19.1%) among the homegardens studied. However, this closely followed the income from pension and business. About 12 % of the respondents came under government jobs as major income source.

4.6.2 Income

Table 50 shows the income group distribution of the 330 homegardens studied in Thrissur district. Annual income of respondents was categorized into six scales. Highest frequency was observed for 2,00,001-5,00,000 scale (count-137; 41.5%). Lowest frequency was observed for <25,000 scale (0.9%). Second highest frequency was observed in 1,00,001-2,00,000 scale (77; 23.3%). Next highest frequency was found in 50,001-1,00,000 scale (63; 19.1%). Only 8.5 % was observed in the highest income class (>5,00,001).

101

Table 47. Occupation of respondents from three size classes of homegarden of selected panchayaths of Thrissur district

Occupation	Size holding						Total	
	Small		Medium		Large			
	Count	%	Count	%	Count	%	Count	%
Agriculture	17	15.4	23	20.9	25	22.7	65	19.7
Business	20	18.2	18	16.4	14	12.7	52	15.7
Government	15	13.6	15	13.6	19	17.3	49	14.8
Daily wages	18	16.4	9	8.2	10	9.1	37	11.2
Foreign	12	10.9	9	8.2	13	11.8	34	10.3
Pension	24	22.8	27	25.5	24	21.8	75	22.7
Private	4	3.6	9	8.2	5	4.5	18	5.5
Total	**110**	**100.0%**	**110**	**100.0%**	**110**	**100.0%**	**330**	**100.0%**

102

Table 48. Occupation of respondent from three eco-regions and a peri-urban area of Thrissur district

Occupation	Eco-region								Total	
	High land		Mid land		Coastal		Peri-urban			
	Count	%	Count	%	Count	%	Count	%	Count	%
Agriculture	24	20.0	17	14.2	16	26.7	3	10.0	60	18.2
Business	16	13.3	17	14.2	15	25.0	6	20.0	54	16.4
Government	23	19.2	20	16.7	2	3.3	5	16.7	50	15.2
Daily wages	18	15.0	17	14.2	9	15.0	6	20.0	50	15.1
Foreign	8	6.7	12	10.0	10	16.7	4	13.3	34	10.3
Pension	28	23.3	34	28.3	8	13.3	6	20.0	76	23.0
Private	3	2.5	3	2.5	0	0.0	0	0.0	6	1.8
Total	**120**	**100.0%**	**120**	**100.0%**	**60**	**100.0%**	**30**	**100.0%**	**330**	**100.0%**

103

Table 49. Major source of income of respondents of all 330 households from selected panchayaths of Thrissur district

Source of income	Frequency	Proportion
Agriculture	63	19.1%
Pension	57	17.3%
Business	51	15.5%
Government	42	12.7%
Foreign	28	8.5%
Daily wages	25	7.6%
Agriculture + Pension	10	3.0%
Others	54	16.3%

Table 50. Income of respondents from 330 households of selected panchayaths of Thrissur district, Kerala

Income	Frequency	Proportion
<25,000	3	0.9%
25,001-50,000	22	6.7%
50,001-1,00,000	63	19.1%
1,00,001-2,00,000	77	23.3%
2,00,001-5,00,000	137	41.5%
>5,00,001	28	8.5%
Total	**330**	**100.0%**

4.6.3 Income and expenditure from homegarden

A comparison of the total income from homegarden and expenditure for homegarden showed that small and medium homegardens were non-profitable (Table 51). Profit was only observed for large homesteads (Rs. 14,924). Small and medium homegardens showed loss from homegardening. Small homegardens had a mean loss of Rs. 2,693.1 per homegarden per year, while medium homegardens had a mean loss of Rs. 5,376.8. Total expenditure for homegardening was quite higher in large homesteads (Rs. 36,337). It was Rs. 35,125 for medium homegardens and Rs. 6,614.5 for small homegardens. Income from different size classes of homegardens was also in the same order of expenditure. Large homegardens generated highest income (Rs. 51,261.2) followed by medium (Rs. 29,748.2) and small (Rs. 3,921.4).

104

Table 51. Income, expenditure and profit of farmers from homegardens during the year 2015

	Mean expenditure (in Rs.)			
	Small	Medium	Large	Total
Income	3,921.4 (14,460)	29,748.2 (39,201)	51,261.2 (59,082.6)	27,021.8 (42,267.1)
Expenditure	6,614.5 (8893.1)	35,125 (19,087.7)	36,337.6 (25,042.2)	19,155.9 (19,245.4)
Profit	-2,693.1 (5566.9)	-5,376.8 (20,113.3)	14,924.2 (34,040.4)	2306.9 (23,021.7)

Table 52. Total expenditure of farmers for the maintenance of homegarden during the year 2015

Homegarden expenditure	Mean expenditure (in Rupee (Rs))			
	Small	Medium	Large	**Total**
Planting	38.2 (313.9)	232.5 (1,179.1)	896.5 (357.7)	420.3 (745.8)
Fertilisers	2,213 (3,899.1)	4,166.7 (4,810)	10,582.4 (9,143.6)	4,013.3 (6,189)
Labourers	3,309.9 (5,008)	10,559.2 (14,283.8)	18,076.5 (17,189.9)	8,587.4 (13,253.4)
Harvesting	1,053.4 (1815.8)	3,166.7 (4,143.8)	6,582.4 (4,452)	2,434.9 (3,680.6)
Total expenditure	6,614.5 (8,893.1)	35,125.0 (19,087.7)	36,337.6 (25,042.2)	19,155.9 (19,245.4)

Total expenditure incurred by the farmer for the maintenance of homegarden varied across size classes of homegardens (Table 52). It was clear that all size classes of homegardens spent more money for labour charge (mean Rs. 8587.4). Highest expenditure for labour charge was observed for large homegardens (Rs. 18,076.5). Medium homegardens spent a sizable amount of money for the labour charge as compared to small homegardens (Rs. 10,559.2). Small homegarden

105

farmers managed to restrict the expenditure for labour charge at a lower level (Rs. 3309.9). The next highest expenditure incurred by farmers for the buying fertilizers (mean Rs. 4013.3). Expense for fertilizer purchase also higher in large homegardens (Rs. 10,582). It was Rs. 4,166.7 for medium homegardens and Rs 2213 for small homegardens. Higher expenditure for harvesting was reported by large homegardens (Rs. 6,582.4). Generally, all expenditure were highest for large homegardens and least for small homegardens.

4.6.4 Details of livestock

Table 53 shows comparison of number of livestock present in homegardens of varying size categories of different eco-regions during 1990 and 2015. All size categories displayed decrease in total number of cattle over 15 years. During 1990s number of cattle was 407 which substantially decreased to 148 by 2015. Before 15 years number of cattle was more in large homesteads (172) compared to midland (137) and small (98) homegardens. During 2015 the number of cattle reduced to 72, 47 and 29 respectively for large, medium and small homegardens. The 15 year time period not only affected number of cattle but also number of poultry. Poultry had a slight increase in number in large homesteads (in 1990, 194 numbers and in 2015, 201 numbers) and other two size classes showed a decreasing trend over 15 years period.

4.6.5 Homegarden fragmentation

Statistics of fragmentation of homegardens from all surveyed panchayaths are shown in Table 54. Out of 330 homegardens 87 were fragmented (26.4%) and 243 homegardens (73.6%) haven't undergone fragmentation. Cause of fragmentation happened by two reasons *viz*; by partition and by sale (Table 55). Partition was the major reason for the fragmentation of homegardens. Out of 87 fragmented homestead 63 (72.4%) were due to partition. Sale was the reason in 18 (20.7%) households. Partition and sale together happened in only 6 homesteads (6.9%).

Fragmentation of homegardens based on eco-region comparison shows fragmentation occurrence was more in peri-urban area (33.3%) followed by

106

midland (30%), highland (24.2%) and coastal (20%) regions (Table 56). Out of 120 homegardens surveyed 36 were fragmented in midland and 29 were in highland. Out of 60 homesteads surveyed in coastal area 12 were fragmented. In peri-urban area 10 were fragmented out of 30 homesteads surveyed.

Table 53. Number of livestock in different size of household during 1990 and 2015

Eco-region	Livestock	Size of household						Total	
		Small		Medium		Large			
		1990	2015	1990	2015	1990	2015	1990	2015
High land	Cattle	19	15	37	8	30	30	86	53
	Poultry	36	29	45	60	71	53	152	142
Mid land	Cattle	56	4	71	17	87	27	214	48
	Poultry	113	77	146	20	77	95	336	192
Coastal land	Cattle	14	5	21	11	46	10	81	26
	Poultry	35	34	102	55	32	26	169	115
Peri-urban	Cattle	9	5	8	11	9	5	26	21
	Poultry	29	33	25	23	14	27	68	83
Grand Total	Cattle	98	29	137	47	172	72	407	148
	Poultry	213	173	318	158	194	201	725	532

Table 54. Homegarden fragmentation of total 330 households from selected panchayaths of Thrissur district

Fragmentation	Frequency	Proportion
Yes	87	26.4%
No	243	73.6%
Total	330	100.0%

107

Table 55. Causes of fragmentation of total 330 households from selected panchayaths of Thrissur district

Causes	Count	Proportion
Partition	63	72.4%
Partition+ sale	18	20.7%
Sale	6	6.9%
Total	87	100.0%

Causes of fragmentation were compared between different eco-regions and peri-urban area describes partition was the major threat in all four regions (Table 57). Coastal area homegardens had the highest percentage of partition (91.7%). It was followed by highland (82.8%), midland (61.1%) and peri-urban area (60%). Sale was more in midland region (30.6%) compared to other regions. Sale was 13.8% in highland, 20 % in peri-urban and the lowest was in coastal area (8.3%). Fragmentation of homegardens based on size class comparison revealed medium homegardens had highest percentage of fragmentation (33.6%) (Table 58). Large homegardens (23.6%) and small homegardens (21.8%) showed near value and small homegardens had the least fragmentation. Out of 87 fragmented homegardens 24 were in small size category, 37 were in medium and 26 were in large categories.

Causes of fragmentation based on all three size classes showed that largest percentage of partition occurred in large homegardens (73.1%) (Table 59). It was 70.8 % in small and 73 % in medium homesteads. Sale was more in small homesteads (25%) followed by large (19.2%) and medium (18.9%). Partition + sale was very high in medium homesteads (8.1%). It was 7.7 % in large homesteads and 4.2 % in small homesteads.

108

Table 56. Fragmentation of homegardens from three eco-regions and one peri-urban area of Thrissur district

Fragmentation	Eco-region								Total	
	High land		Mid land		Coastal		Peri-urban			
	Count	%	Count	%	Count	%	Count	%	Count	%
Yes	29	24.2	36	30.0%	12	20.0	10	33.3	87	26.4
No	91	75.8	84	70.0	48	80.0	20	66.7	243	73.6
Total	120	100.0%	120	100.0%	60	100.0%	30	100.0%	330	100.0%

Table 57. Causes of fragmentation of homegardens from three eco-regions and one peri-urban area of Thrissur district

Causes	Eco-region								Total	
	High land		Mid land		Coastal		Peri-urban			
	Count	%	Count	%	Count	%	Count	%	Count	%
Partition	24	82.8	22	61.1	11	91.7	6	60.0	63	72.4
Sale	4	13.8	11	30.6	1	8.3	2	20.0	18	20.7
Partition+sale	1	3.4	3	8.3	0	0.0	2	20.0	6	6.9
Total	29	100.0%	36	100.0%	12	100.0%	10	100.0%	87	100.0%

Table 58. Fragmentation of homegardens based on size of holding of selected panchayaths of Thrissur district

Fragmentation	Size of holding						Total	
	Small		Medium		Large			
	Count	%	Count	%	Count	%	Count	%
Yes	24	21.8	37	33.6	26	23.6	87	26.4
No	86	78.2	73	66.4	84	76.4	243	73.6
Total	110	100.0%	110	100.0%	110	100.0%	330	100.0%

Table 59. Causes of fragmentation based on size of holding from selected panchayaths of Thrissur district

Causes	Size of holding						Total	
	Small		Medium		Large			
	Count	%	Count	%	Count	%	Count	%
Partition	17	70.8	27	73.0	19	73.1	63	72.4
Sale	6	25.0	7	18.9	5	19.2	18	20.7
Partition + Sale	1	4.2	3	8.1	2	7.7	6	6.9
Total	24	100.0%	37	100.0%	26	100.0%	87	100.0%

4.6.6 Constraints in homegardening

Interest of farmers in planting trees in their homegarden delivered noticeable figures from their responds (Table 60). Out of 330 respondents 233 (70.6%) were interested in planting trees in their homesteads. But 97 (29.4%) were not interested in planting trees in their premises.

Table 60. Interest of respondents in planting trees in their homegarden from selected panchayaths of Thrissur district

Interest	Frequency	Proportion
Yes	233	70.6%
No	97	29.4%
Total	330	100.0%

Table 61. Major constraints in homegardening for all 330 households from selected panchayaths of Thrissur district

Constraints	Frequency	Proportion
High wage	168	50.9%
Less labour availability	122	37%
Large expense/Less profit	95	28.8%
Pest and disease	50	15.1%
Water scarcity	30	9.1%
Less market price	24	7.3%
Less area for homegardening	20	6.1%
Less market availability	1	0.3%
Other constraints	23	7%
No constraints	24	7.3%

There were nine prominent constraints in homegardening obtained by the questionnaire survey conducted for farmers of selected homegardens (Table 61). Out of 330 households 168 responded high wage as their major constraint

(50.9%). Less labour availability was the major constraint for 122 respondents (37%). Large expense (28.8%), pest and disease (15.1%), water scarcity (9.1%), etc. were the other constraints. Less area for homegardening was an important constraint for 20 respondents (6.1%). Other constrains such as no time for homegardening, unavailability of land owner for proper caring, wild animal and other animal conflicts and lack of interest constituted 7 % of total constraints. There were 24 farmers (7.3%) who had no constraints in homegardening.

Comparison of major constraints of homegardening based on eco-regions is shown in Table 62. High wage was the major constraint of all regions. It was highest in coastal area (70%). Less labourer availability was the next major constraint which was the second highest constraint in all regions except peri-urban area. More expense (11%) was the second highest constraint in peri-urban area. Water scarcity was a major problem in coastal area (21.6%). In midland 10.8 % of respondents had no constraints. In highland it was 1.7 %, coastal area 10 % and in peri-urban area 7.3 %.

High wage was the major constraint in all size classes of homegarden (Table 63). It was more in small homesteads (56.3%) and least in large (45.4%). It was 51.8 % in medium homegardens. Less labourer availability was the second highest constraint of all size classes. It was more in large homesteads (41.8%). More expense and pest and disease were the other constraints which can see in all three size classes. Less area for homegardening was an important constraint observed in small homesteads.

4.7 WOOD QUALITY ASSESSMENT USING NON-DESTRUCTIVE TECHNIQUES

4.7.1 Oven dry specific gravity

Oven dry specific gravity ($SPG_{o.d}$) of the three major timber species is shown in Table 64. *Tectona grandis* showed slight variations of $SPG_{o.d}$ across three eco-regions such as highland, midland and coastal area. Coastal land had highest $SPG_{o.d}$ for teak (0.69). However, it exhibited statistically non-significant

112

difference between all three eco-regions. *Artocarpus heterophyllus* had highest $SPG_{o.d}$ in both highland region and coastal land (0.53). It also had non-significant difference between three eco-regions, whereas *Swietenia macrophylla* had highest value for both highland and midland (0.5). It also had non-significant difference across the eco-regions.

Comparison of the oven dry specific gravity of major timber species based on girth classes also displayed slight changes (Table 65). *Tectona grandis* had highest $SPG_{o.d}$ at both 10-50 cm and 101-150 cm girth scales (0.69) and least in 51-100 cm scale (0.67). *Artocarpus heterophyllus* had highest value in 10-50 cm girth class while *Swietenia macrophylla* showed high value in both 51-100 cm and 151-200 cm girth classes. But all these comparisons were statistically non-significant.

4.7.2 Modulus of Elasticity

Dynamic Modulus of Elasticity (MOE_{dyn}) estimated for *Tectona grandis* was highest in midland region (6611116.48) and least in highland region (6367378.12) (Table 66). *Tectona grandis* did not show significant difference of MOE_{dyn} between eco-regions. But, *Artocarpus heterophyllus* had significant difference of MOE_{dyn} between three eco-regions at 1 % level. Highest MOE_{dyn} of *Artocarpus heterophyllus* was estimated in highland region (4015343.05). Comparison of MOE_{dyn} of *Swietenia macrophylla* showed significant difference at 5 % level across eco-regions. It also had highest MOE_{dyn} at highland region (3774734.86).

Comparison of MOE_{dyn} of major timber trees based on different girth classes revealed that *Tectona grandis* had highest MOE_{dyn} at 101-150 cm girth class (6775692.56) (Table 67). Least MOE_{dyn} was observed at 51-100 cm girth class (6184541.8). *Artocarpus heterophyllus* showed highest MOE_{dyn} at 151-200 cm girth class (3778601.33) and *Swietenia macrophylla* had at 10-50 cm girth class (3671008.35). However, all these comparisons were statistically non-significant.

Table 62. Major constraints in homegardening from three eco-regions and peri-urban area of Thrissur district

High land			Mid land			Coastal			Peri-urban		
Constr.	Count	%	Constr.	Count	%	Constr.	Count	%	Constr.	Count	%
1	62	51.7%	1	50	41.7%	1	42	70%	1	14	46.7%
2	41	34.17%	2	46	38.3%	2	26	43.3%	5	11	36.7%
5	24	20%	5	36	30%	3	13	21.6%	2	9	30%
6	18	15%	6	15	12.5%	6	9	15%	6	7	23.3%
11	11	9.2%	9	13	10.8%	5	5	8.3%	4	4	13.3%
12	2	1.7%	12	13	10.8%	12	6	10.0%	12	24	7.3%

(1-High wage, 2-Less labourer availability, 3-Water scarcity, 4- less area for homegardening, 5- more expense, 6- Pest and disease, 9-Less market price, 11- other constraints (threat from animals, soil problems, no time for homegardening, lack of interest), 12- No constraints)

Table 63. Major constraints in homegardening from all three size categories

Small			Medium			Large		
Constr.	Count	%	Constr.	Count	%	Constr.	Count	%
1	62	56.3%	1	57	51.8%	1	50	45.4%
2	37	33.6%	2	39	35.4%	2	46	41.8%
5	23	20.9%	5	28	25.4%	6	16	14.5%
4	18	16.4%	6	21	19.1%	5	15	13.6%
6	12	10.9	9	13	11.8%	3	10	9.1%
12	10	9.1%	12	12	10.9%	12	2	1.8%

(1-High wage, 2-Less labourer availability, 3-Water scarcity, 4- less area for homegardening, 5- more expense, 6- Pest and disease, 9- Less market price, 12- No constraints)

Table 64. Oven dry specific ($SPG_{o.d}$) gravity of major timber species obtained by NDT techniques across different eco-region of Thrissur district

Species	Eco-region			F value
	Highland	Midland	Coastal land	
Tectona grandis	0.68 (0.024)	0.68 (0.044)	0.69 (0.048)	0.161^{ns}
Artocarpus heterophyllus	0.53 (0.013)	0.51 (0.020)	0.53 (0.026)	2.674^{ns}
Swietenia macrophylla	0.5 (0.015)	0.5 (0.016)	0.49 (0.013)	0.259^{ns}

ns: non-significant at 5% level; Value in the parenthesis shows standard deviation

Table 65. Oven dry specific gravity ($SPG_{o.d}$) of major timber species of different girth classes obtained by using NDT techniques

Species	Girth classes (cm)				F value
	10-50	51-100	101-150	151-200	
Tectona grandis	0.69 (0.038)	0.67 (0.043)	0.69 (0.037)	0.68 (0.042)	0.267^{ns}
Artocarpus heterophyllus	0.54 (0.020)	0.52 (0.021)	0.51 (0.022)	0.53 (0.018)	2.346^{ns}
Swietenia macrophylla	0.49 (0.014)	0.5 (0.010)	0.49 (0.013)	0.5 (0.015)	2.517^{ns}

ns: non-significant at 5% level; Value in the parenthesis shows standard deviation

Table 66. Dynamic Modulus of Elasticity (MOE_{dyn}) of major timber species across different eco-regions of Thrissur district

Species	Eco-region			F value
	Highland	Midland	Coastal land	
Tectona grandis	6367378.12 (1110501.70)	6611116.48 (1410631.66)	6409081.61 (1372547.81)	0.120^{ns}
Artocarpus heterophyllus	4015343.05 (442882.39)	2986653.76 (423824.40)	3684667.80 (565057.65)	14.285**
Swietenia macrophylla	3774734.86 (463865.20)	3624829.49 (482899.56)	3240313.52 (472160.19)	4.075^{*}

ns: non-significant at 5% level; Value in the parenthesis shows standard deviation; **: Significant at 1% level; * Significant at 5% level

Table 67. Dynamic Modulus of Elasticity (MOE_{dyn}) of major timber species of different girth classes

Species	Girth classes (cm)				F value
	10-50	51-100	101-150	151-200	
Tectona grandis	6612076.88 1231719.54	6184541.83 1159996.71	6775692.56 1617595.83	6277790.345 1154522.26	0.408^{ns}
Artocarpus heterophyllus	3708373.41 (652257.05)	3476443.12 (565658.50)	3285468.29 (751834.78)	3778601.33 (548893.87)	1.133^{ns}
Swietenia macrophylla	3671008.35 (568189.18)	3447404.72 (479240.83)	3441458.57 (516840.29)	3626632.18 (532204.28)	0.465^{ns}

ns: non-significant at 5% level; Value in the parenthesis shows standard deviation.

DISCUSSION

DISCUSSION

5.1 TREE DIVERSITY

5.1.1 Total species diversity

Total species identified from selected 330 homegardens of Thrissur district was 163. It comprises a total 102 tree species and 41 agricultural crop species (Table 2). Total species diversity, tree species diversity and agricultural crop diversity were declining over large, medium and small respectively. Total tree diversity encountered from selected homegardens of various eco-regions of Thrissur district was 122 species. Three size classes of homegardens showed variation in species diversity (Fig 13). Interestingly, large homesteads registered highest species diversity with 102 species. Midland had a modest share of tree diversity with 95 species and small gardens had the lowest with 85 species.

A recent study in three districts of central Kerala identified 208 tree species from homegardens (Kumar, 2011). The study also showed species presence in different size classes such as small, medium and large were 145, 173, and 138, respectively. Contrary to this, the present study showed large homegardens giving highest tree diversity. May be the large space availability for the planting of trees is the reason for high diversity in large homesteads. Yet another study in the homegardens of Uttara Kannada district in Western Ghats identified 68 species and a total of 673 individuals from the selected 68 homegardens (Shastri *et al.* 2002). In the present study medium homegardens maintained a modest diversity which was not far below the large homegardens. Farmers of medium homegardens utilize homegardens optimally. More number of useful species would be occupied in these gardens in an effective way to maximise livelihood needs of farmers. This may lead to the increased diversity in medium homegardens. The less availability of space for planting would be the reason behind the least diversity in small homegardens.

Meanwhile, past study found 127 tree species from the homegardens of 17 selected taluks of Kerala state (Kumar *et al.*, 1994). However, all these old studies were not concentrated in Thrissur district. May be large number and extensively spread of samples were the reasons for higher number of diversity in all these previous studies. Above all, the reduced tree diversity of present study than the older studies (Kumar *et al.*, 1994 and Kumar, 2011) reveals the trend of decreasing species diversity among homegardens over time. Population pressure and skewed land availability may have negatively affected the species diversity in homegardens. The fast changing socio-economic equations in the state of Kerala had serious impacts on the functioning of homegardens as well. Probably, the demographic pressure on the land and concomitant fragmentation has led to the conversion of land for other non-agricultural activities, which were by and large as the cost of the loss of homegarden area.

Selected homegardens of various eco-regions differ in species diversity (Fig 14). Midland region of the state constitute the most thickly populated regions and the consequent high agriculture pressure on the land. Furthermore, the soil in this region is more productive as compared to the high land and coastal regions. The high diversity in midland region could be attributed to these facts. Highland is less populated as compared to midland and peri-urban area and hence the dependence on the homegardens for diverse end use may be comparatively less in the highland region. This could be the probable reason for the relatively less diversity in the highlands

Demographic pressure on the land significantly influences the land use patterns in the tropics. Homegardens in Kerala are constrained by the availability of land. Population growth and associated land fragmentation probably multiply the adversities. In addition, the changing socio-economic trends bring largescale conversion of land for other non-agricultural purpose. Increasing migration to the urban areas is yet another deterrent in the shrinkage of homegarden areas and decline in their quality. Population increase will result the shortage of land for cultivation and increased demand for food lead to farming in forest reserve lands

120

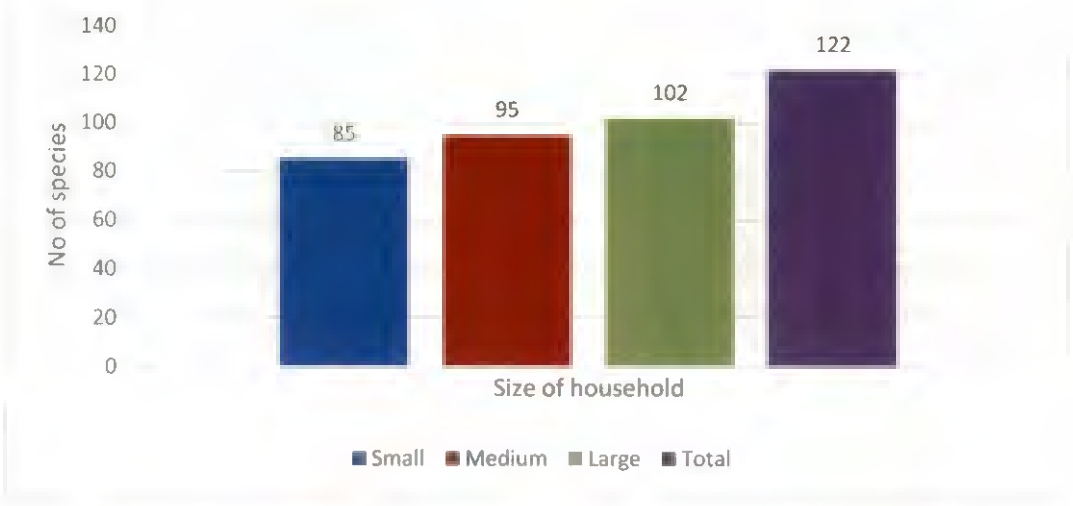

Fig 13. Total tree diversity of varying size classes of homegardens of Thrissur district, Kerala

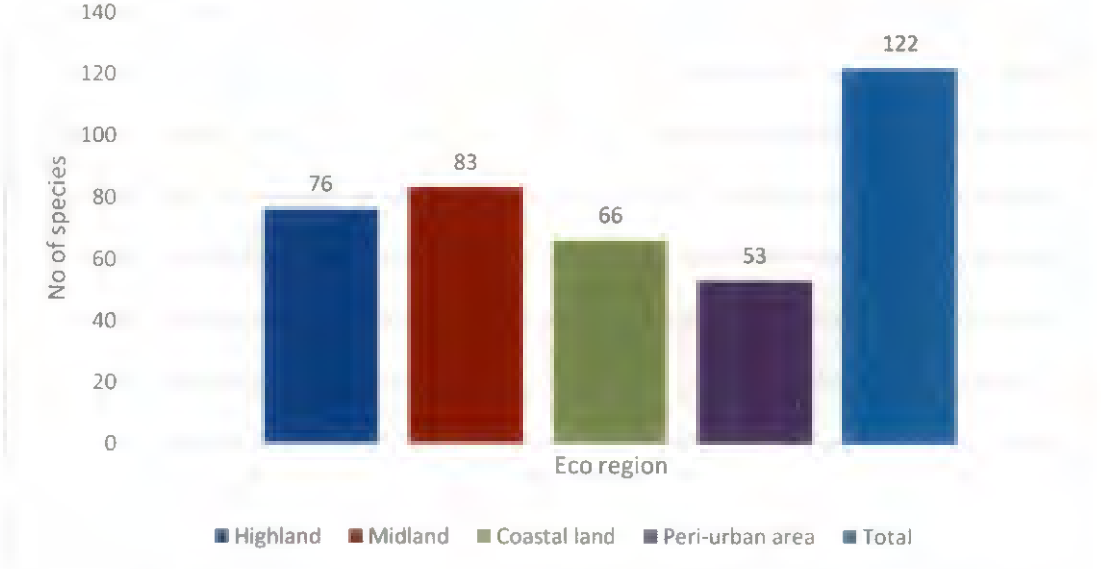

Fig 14. Total tree diversity of different eco regions of Thrissur district, Kerala

causing environmental deterioration and rural to urban migration (Klausner, 1960). The edapho-climatic conditions in the coastal regions puts serious limitations on agricultural production which also affected the plant diversity in the homegardens in these regions. Poor fertility consequent to salinity and poor drainage of soil were the main problem for the cultivation of the crops. This could be the major reason for the poor diversity in the homegardens of coastal regions as compared to midlands and highlands. A study conducted in Vietnam revealed that diversity of most of the functional groups of trees species and agricultural crops were highest in the midland homegardens (Trinh *et al.*, 2002). In yet another study highland homegardens showed a lower species diversity and simpler species composition when compared to lowlands (Karyono, 1990). In the present study most of the functional groups were higher in midland region closely followed by highland region and least in coastal land. But in Vietnam study second most diversity observed in lowland and least in mountain land.

Diversity indices such as Shannon Wiener Diversity Index and Simpson Diversity Index of total tree species identified from selected panchayaths of Thrissur district were 3.43 and 0.93 respectively. A previous study in Kerala homegardens of various taluks found that Simpson Diversity Index ranged from 0.25 to 0.75 and Shannon Wiener Diversity Index ranged from 1.129 to 3.016 (Kumar *et al.*, 1994). A recent study in homegardens of Kerala revealed Simpson Diversity indices of all plant species of small, medium and large homegardens were 0.64, 0.41 and 0.46 respectively (Kumar, 2011). Greater value of Shannon Wiener Diversity Index and Simpson Diversity Index of present study than the older study suggested the greater species diversity and evenness of Kerala homegardens. Both indices did not show a marked variation among size categories of homegardens. Greater value of Simpson Diversity Index indicates a greater similarity in abundance of every species among all size categories. These higher values could be attributed to the confinement of the present study to a smaller region of the state, while the earlier studies had more sample size representing major part of Kerala. In spite of these higher species diversity

122

indices, present study identified lesser number of species in Kerala homegardens than the older studies.

5.1.2 Functional diversity

Kerala homegardens were not only diverse in species number or structural variability, but was more diverse in functional groups of plants. Functional diversity of the homegardens refers to the grouping of components based on the preference of farmers. Most abundant functional group of trees found in surveyed homegardens was timber species (53 species) and second most abundant species was fruit trees (39 species). Farmer's preference for more of economically important tree species could be the reason for this trend. The species diversity in homegarden is closely linked to the functional priorities of farmers. This however, may vary with regions and geographic conditions. For example Peruvian homegardens consists more fruit trees such as *Mangifera indica L., Eryngium foetidum L., Syzygium sp., Cocos nucifera L.*, etc. (Perrault-Archambault and Coomes, 2008). High diversity of timber species in homegardens was a true reflection of the farmer's preferences. Most of the fruit trees also can be included in the timber group of trees. So the fruit tree diversity also was high in most of the homegardens.

5.1.2.1 Functional diversity and garden size

There was considerable difference in the functional diversity among the various size classes of homegardens (Fig.15, 16 and 17). In general, the diversity was more in large homegardens (102) followed by medium (95) and small gardens (85). Large homegarden farmers seem selective for more economic crops or trees. The trends in the present study shows a clear shift in the homegarden diversity with holding size. For instance, most of the earlier studies in Kerala showed high species diversity associated with small homegardens and lowest in the large gardens (Kumar *et al.*, 1994; Kumar, 2011). In a study two decades back, small homegardens in the state had 116 number of woody taxa as compared to large homegardens (32 woody taxa) (Kumar, 1994). The probable reason for

123

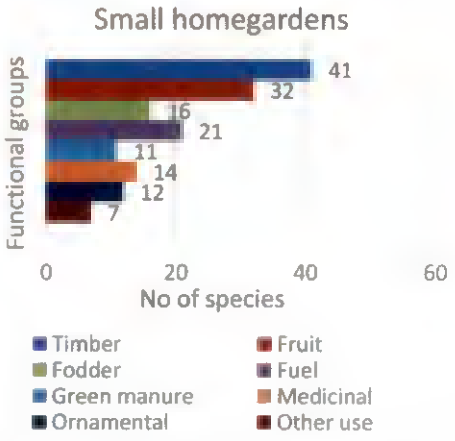

Fig 15. Functional diversity of small homegardens of Thrissur district, Kerala

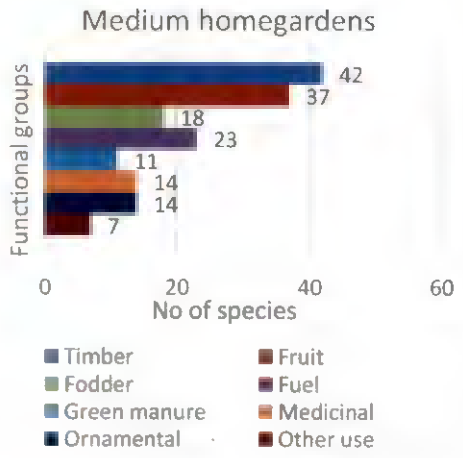

Fig 16. Functional diversity of medium homegardens of Thrissur district, Kerala

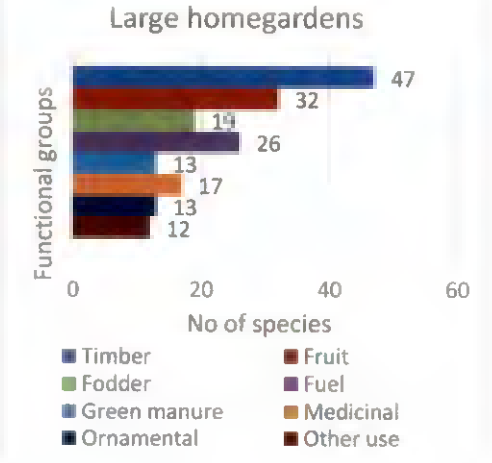

Fig 17. Functional diversity of large homegardens of Thrissur district, Kerala

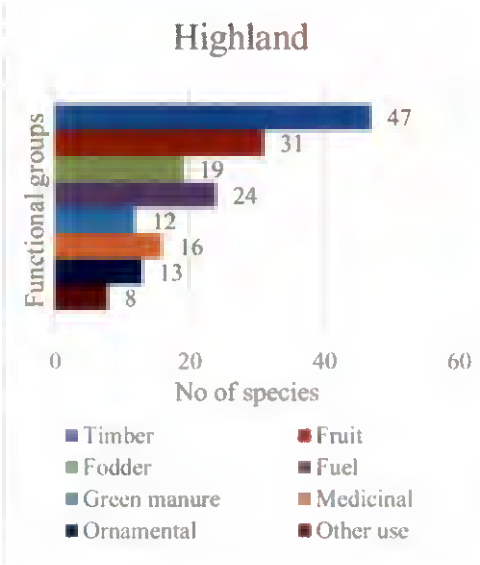

Fig 18. Functional diversity of homegardens from highland region of Thrissur district, Kerala

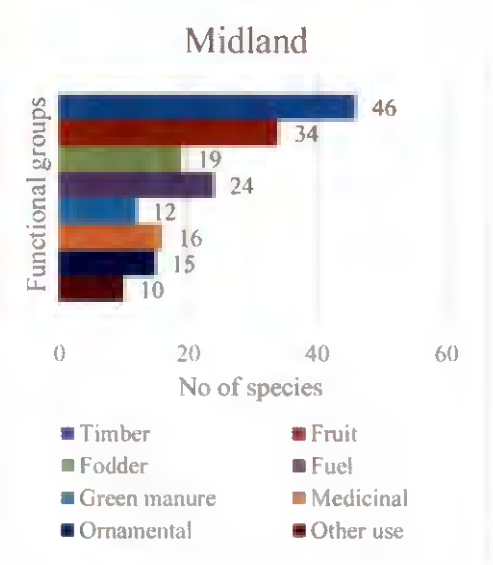

Fig 19. Functional diversity of homegardens from midland region of Thrissur district, Kerala

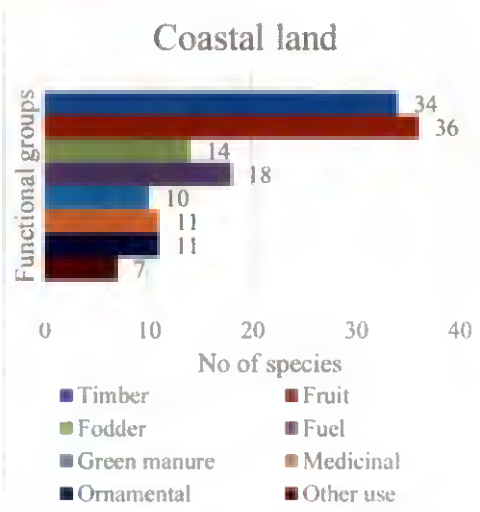

Fig 20. Functional diversity of homegardens from coastal land region of Thrissur district, Kerala

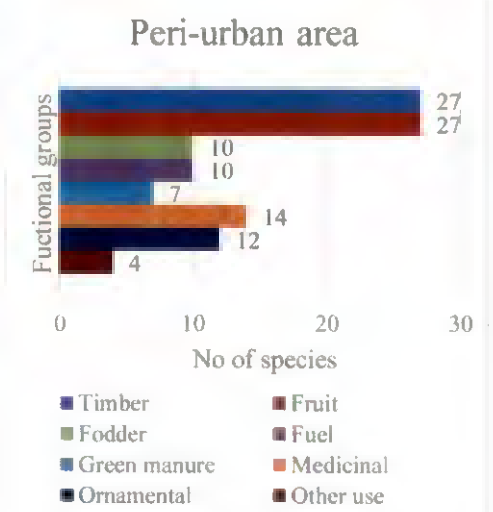

Fig. 21. Functional diversity of homegardens from peri-urban region of Thrissur district, Kerala

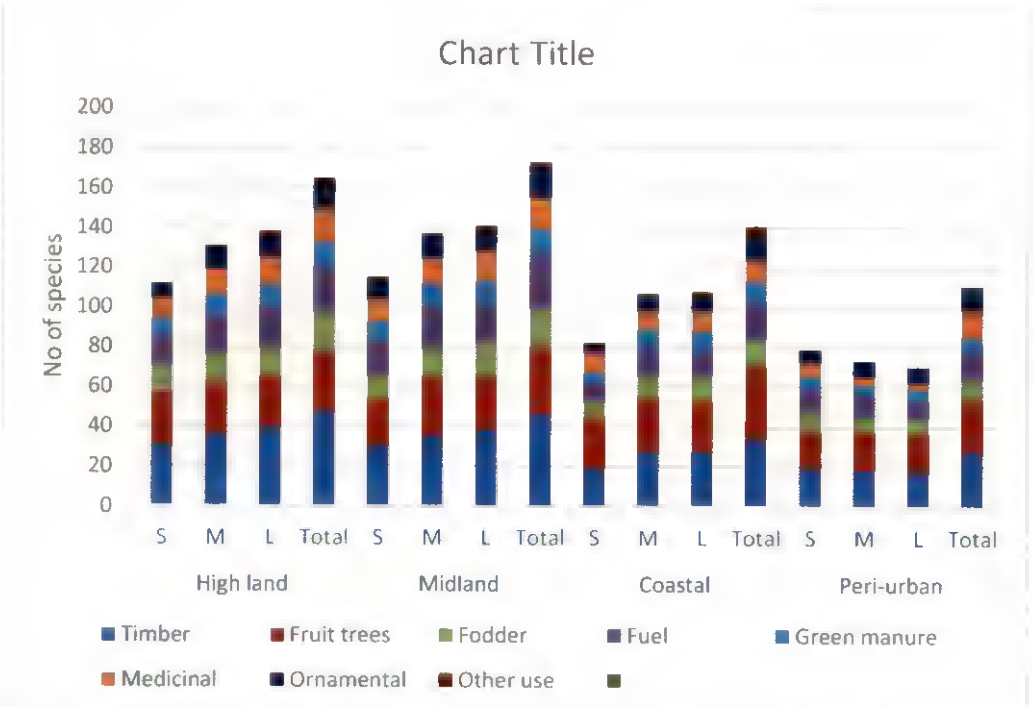

Fig 22. Functional diversity of homegardens from varying size categories of different eco regions of Thrissur district, Kerala

this clear cut shift in diversity could be the paradigm shift in socio-economic fabric of the state. During earlier times the smaller homegardeners maintained intimate association with the garden premises for diverse components linked with their food and nutritional security (Kumar and Nair, 2004). Obviously, the functional diversity of the small homegardens were higher. However, with the change in the economic options consequent to increased foreign remittance and preference for white collar jobs led the farming community including small farmers to drift away from agriculture practices especially traditional homegardening. This shift had seriously impacted the diversity and abundance of trees in the small homegardens. The high wage rates and low value for homegarden products further aggravated the situation. However, the large homegardens by virtue of their large land available retained more species of economic benefits. Contrary to the earlier practice of extensive single species cultivation in large homegardens, the present practices promote multi species cultivation practices in large homegardens. For instance many large homegardens prefer tree dominated integrated land use practices. It may cause the higher diversity of timber and fuel tree species in large homegardens. Replacement of labour intensive cash crops such as coconut and arecanut with less labour intensive fruit trees and timber tree species may also had contributed to increased number of species in large homesteads. Comparison of tree diversity among size classes of homegardens within eco-regions also shows considerable variation (Fig 22).

5.1.2.2 Diversity and eco-regions

The eco-region wise comparison also showed timber trees topped the list in each region followed by fruit trees. It revealed the clear dominance of timber trees and fruit trees in every homegardens of Thrissur district. This implies the true economic preference of farmers within the homegardens of Thrissur district. Highland and midland listed almost equal number of timber species (47 and 46 respectively) (Fig 18 and 19). Even though coastal land exhibited a decreased diversity of timber species, it had highest diversity of fruit trees (Fig 20).

Mangifera indica, Syzygium cumini, Artocarpus hirsutus, etc. were the frequently observed species in costal land. The rich functional diversity of timber trees and fruit trees has been reported from many tropical homegardens across the world. For instance, in central Sudan fruit trees were the main crop of 76 homegardens out of 81 surveyed (Gebauer, 2005). Report from Uttara Kannada district in western ghats reveals out of 68 tree species identified from 34 homegardens dominant species were *Mangifera indica, Artocarpus heterophyllus* and *Erythrina indica* (Shastri *et al.,* 2002).

The nature and fertility of soil, presence of salt contents etc. might be affecting the species distribution in coastal land. The human pressure and skewed land availability severely affected the diversity in peri-urban areas. All functional groups registered lowest diversity in peri-urban area (Fig 21). A study in homegardens of Nepal found that species diversity varied with eco zones (Gautam *et. al.* 2004). It varied from hill region to terai region (plane region) and from eastern region to western region. Diversity was higher in eastern parts of the country than western parts and it was highest in hills than terai. Several studies mentioned that species diversity affected by several ecological factors such as temperature, soil type, stresses and other climatic parameters (Sunwar, 2003; Shrestha *et al.*, 2002). Another study conducted in Vietnamese homegardens revealed that plant species diversity varied along the north–south gradient of the country. Among the four regions (North mountains, Central midlands, South lowland and Mekong Delta) highest diversity observed for homegardens of selected delta region and least observed in central midland homegardens (Trinh *et al.*, 2003).

5.1.2.2 Abundance of timber tree species of Thrissur district

The projected number per hectare of important timber species of Thrissur district provided clarity on the preference of farmers on the choice of species. (Table 11). It is evident that *Mangifera indica* topped the list over other timber trees in homegardens (Fig 23, 24 and 25). Despite the utility of mango as a timber tree species, it was primarily grown for fruit. Probably, it assumed timber value

128

when the fruit yield decline with age. It possess an average number of 11 individual trees per hectare and an estimated number of 15,98,849 individuals in the whole district. *Mangifera indica* is a multipurpose tree used for several useful purposes for farmers. It is used as timber, fodder, fuel, fruit and green manure. Data from all three size categories of all eco-regions displayed appreciable abundance of *Mangifera indica* as timber, fruit tree, fodder tree, fuel and green manure. It was prominent species in large homegardens of each eco-region and least observed in small homegardens. In a broader perspective it was dominated in large homesteads of selected panchayaths (Table 18). Large homegardens usually contains multiple number of *Mangifera indica* and consider mango cultivation as a commercial venture while small and medium farmers grow it for own domestic consumption. Studies else where also showed high mango tree abundance in homegardens. For instance, study from Uttara Kannada village Sirsimakki in Western Ghats founds that out of 93 species with 952 individuals identified from the selected agro-eco systems (including homegardens, paddy land and areca garden boundary predominant ten species account for 55.1 % of the total tree population. *Mangifera indica* topped the list with 100 individuals followed by *Artocarpus heterophyllus* with 74 individuals. (Shastri *et al.*, 2002).

Next to mango, *Artocarpus heterophyllus* was the topper in terms of abundance. It was an important tree species used as timber, fruit and fodder. It had a mean number of 7 trees per hectare. The overall standing number estimated for the entire Thrissur district was 9,63,928 trees. Only coastal land and peri-urban area exhibited least number of jack. The common limitations which affected the abundance of other species in these regions would have affected the abundance of jack also. As a valuable timber and fruit tree it had highest abundance in large and medium homegardens.

Tectona grandis is one of the most valuable and preferred timber species in homegardens of Kerala. These were mostly seen as boundary planting in homegardens. Teak was seen as almost equal number of jack tree in per hectare basis. Being an economically important tree species, farmer preference is always

129

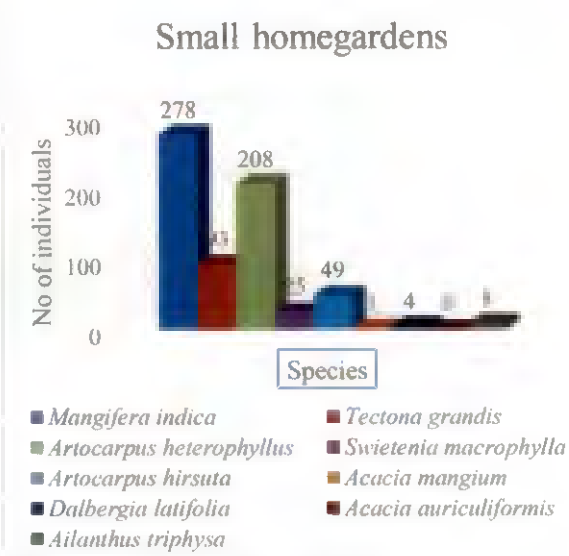

Fig 23. Abundance of timber species in small homegardens of selected panchayaths of Thrissur district, Kerala

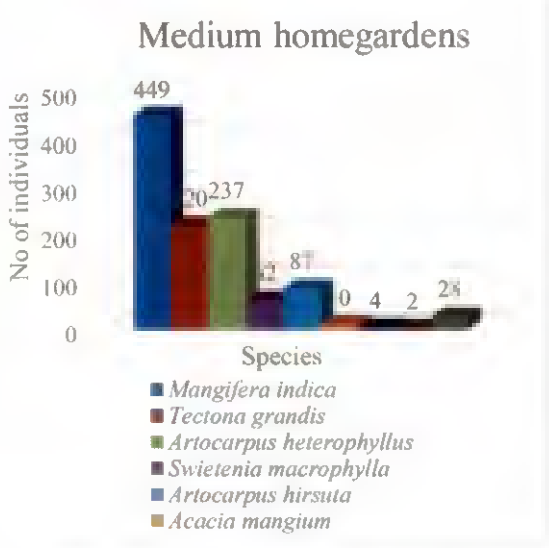

Fig 24. Abundance of timber species in medium homegardens of selected panchayaths of Thrissur district, Kerala

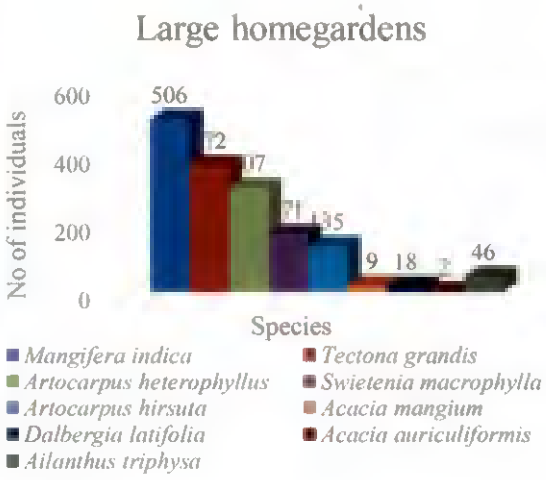

Fig 25. Abundance of timber species in large homegardens of selected panchayaths of Thrissur district, Kerala

inclined to teak. Normally the species consume large growing space and may hinder the growth of other agricultural crops. Hence, teak is preferred in the farm boundaries. This is why the medium and large households maintain more of teak in their premises especially in the boundaries. On account of the economic advantages, there is renewed interest among the farmers to plant more teak in the homegardens. Teak and jack were the predominant timber species in the state that constitute the Trees Outside Forests (TOF) sector (FSI, 2015). One of the major player in the supply of teak in the state is the Kerala Forest Department. However, almost 35 % of the supply of teak to the domestic market is through homegardens while the KFD share is limited to a bare minimum of 2 % (Krishnankutty and Chundamannil, 2012). In the changing scenario of decline in tree stocking in the homegardens of Kerala, there is felt need to increase stock of valuable species like teak and jack in the homegardens of Kerala.

Our study also highlights the prominence of mahogany (*Swietenia macrophylla)* especially in the larger homegardens of coastal regions. In general the abundance was relatively less in all categories of homegardens in the highland, midland and peri-urban regions. But it had considerable number in the coastal land. Like mango trees the coastal land farmers prefer mahogany in their homegardens. May be the high resistance of mahogany towards salt affected soil and deep and strong root systems even in loose soil caused large preference in coastal lands. In homegardens of Rangpur district of Bangladesh Mahogany ranked fourth position in terms of abundance. Study conducted in 64 homegardens of Rangapur district of Bangladesh found that Mango ranked second (n =362, 21.66% of total tree abundance), Jackfruit ranked third (n =178, 10.65%) and Mahogani ranked fourth (n= 146, 8.73%) positions in terms of abundance (Jaman *et al.*, 2016). Mahogany bagged considerable attention in the recent times on account of its fast growth and commercial value. As in the case of teak, this species also consume considerable growing space which could be the lesser preference in the small and medium homegardens with their inherent space limitations. However, with faster growth and high timber value mahogany enjoy a promising space in the TOF sector of Kerala.

131

Artocarpus hirsutus was yet another species of timber value in the Thrissur district. Apart from its timber value *A. hirsutus* has fruit and fodder value. In general, the abundance of *A. hirsutus* was low compared to other timber species in the Thrissur District. The average number per ha was only two considering the various size classes. However, there good abundance of this species observed in the coastal region. Coastal regions by virtue of their growth limitations support only very less diversity tree species. Hence, promotion of *A. hirsutus* would be a better option in vegetating this fragile region. The positive factors for the high abundance of mango and mahogany in coastal land also may influenced the high abundance of *A. hirsutus* there. The large space occupancy of this species may affected its preference in homegardens. Huge space consumption in terms of crown spread may cause potential limitation in integrating other speices which cause the lack of interest of small farmers in planting *A. hirsutus* in their gardens.

5.2 STANDING STOCK OF TREE SPECIES

5.2.1 Standing stock of major timber tree species of Thrissur district

The results on the computation of standing stock of major timber species suggested mango enjoys the highest standing volume of 12.76 m^3 ha^{-1} followed by teak (10.65 m^3 ha^{-1}) in the homegardens of Kerala. Jack constitute the 3rd important timber tree species in the Thrissur district with average standing stock 10 m^3 ha^{-1}. The total timber tree stock was 55.12 m^3 ha^{-1}. Total standing stock of important timber trees in the Thrissur district (only TOF) was estimated to be 8.13 million m^3. As per the FSI latest reports the standing stock of trees in the TOF sector in the state of Kerala is to the tune of 49.06 million m^3 (FSI, 2015). This estimate however may not include mango as it is considered as horticultural crop. This indicates the mango, teak and jack contribute major share to the growing stock in the TOF sector in the state. For instance, these three species constitute 73.1 % of the total timber species present in the Thrissur district. An earlier study conducted on standing stock of timber species in selected taluks of Kerala state suggested average commercial standing stock of homesteads ranged from 6.6 to 50.8 m^3 ha^{-1} and fuel wood volume was ranged from 23 to 86 m^3 ha^{-1} (Kumar *et*

132

al., 1994). Thalappilly taluk of Thrissur district alone constituted of 27.21 m^3 ha^{-1} of standing stock of timber species. But the lion's share was of standing stock of coconut palms. Present study estimated the wood standing stock without considering coconut. Coconut was considered as agricultural crop in this study. As the abundance was very high, standing stock also was highest for *Mangifera indica*. It was followed by *Tectona grandis, Artocarpus heterophyllus* and *Artocarpus hirsutus*. One major outcome of the present study is the quantitative information made available on species-wise standing stock for the district. These base line information will be helpful while developing tree planting programmes for the Thrissur district. Such district-wise information need to be generate for the state of Kerala especially in the context of state and central governments planning greening programmes such as Green India Mission and Haritha Keralam.

Assessing standing stock of timber trees in homegardens of Kerala has significance in the present scenario. The knowledge of supply of timber for the household purposes and for industrial purposes are important. It is essential to understand whether the supply meets the demand from the respective consumers. For instance, some reports observe that 70 to 84 % of the commercial timber requirements of peninsular India met from the tropical homegardens itself (Krishnankutty,1990; Kumar and Nair, 2004) and 70 % of the saw logs in Bangladesh came from homesteads (Singh, 1987). Some of the valuable and good quality timber species had lesser standing stock in all eco-regions of Thrissur district.

5.3 ABUNDANCE OF OTHER TREE SPECIES

Apart from the dominant fruit tree species such as mango, jack and *A. hirsutus*, other fruit species of relevance in the district include *Anacardium occidentale, Tamarindus indica, Artocarpus altilis*, *Garcinia gummi-gutta*, etc. Distinctly large homegardens showed more number of individuals of these species closely followed by medium gardens. The abundance of these species in the small homegardens were very less. Fruit trees are the most prominent functional group in the traditional homegardens of Kerala. The dependence on fruit trees for food

and nutrition has seriously declined over years in the traditional homegardens. The impact of commercialization and land fragmentation could be the major drivers of this change (Kumar and Nair, 2004). Large scale fruit tree cultivation practices are uncommon in Kerala due to space constraints and traditional homegardens were the main source of fruits. Recently, majority of traditional homegarden farmers have shifted to profit oriented modernized farming systems. Introduction of cash crops such as rubber, arecanut, coffee, etc. resulted important structural and functional changes in homegardens. Canopy stratification and species diversity became reduced notably in respect to species producing fruits and nuts, timber, and medicines (Peyre *et al.*, 2006). However, with the changing consumerism, Keralites are more preferring purchases from the local marker that are flooded with various fruit species coming from other states.

Macaranga peltata was a common multipurpose tree species in the homegardens of Kerala. Primarily it was used for fodder, fuel and as green manure tree. The bark and leaves of this tree is used as green manure and it was scattered within the homegardens. Interestingly, it was totally absent in coastal panchayaths. The edaphic limitations may have affected the presence of this species in coastal land. Yet another green manure species of importance is *Gliricidia sepium.* It is a common fodder species also. It was mainly planted in borders of gardens and used as live fences. It is obvious that irrespective of size class it is an important component of all homegardens. Even though it is a common species its number was very less among the homegardens surveyed. Probably farmers restrict the tree growth by continuous lopping for green manure or fodder (Table 23).

Kerala homegardens are the hub of medicinal trees. Rao and Rao (2006) observed in developing countries about 80 % people use medicinal plants from their homegarden for treating various illness and to improve health conditions. The present study also highlight the high diversity of medicinal trees. Most of the trees present in homegardens had some kind of medicinal value. A study in Kalliasseri panchayat of Kannur district of Kerala identified 162 medicinal plants,

which includes trees, herbs and shrubs (Sreedharan, 2004). *Azadirachta indica, Annona squamosa, Strychnos nux-vomica, Cinnamomum zeylanicum, Hydnocarpus pentandra, Phyllanthus emblica* are example for major medicinal trees those have medicinal values also. *Azadirachta indica* was the predominant medicinal tree recorded from all size categories of all eco-regions. Large and medium homegardens of every eco-region had no large difference in abundance of neem tree (Table 24). Most of the homegardens contain neem tree not in large numbers but they maintained one or two individuals for their medicinal purposes. But in case of *Annona squamosa* and *Strychnos nux-vomica* they grow in large numbers around the garden without proper care.

5.4 STRUCTURE OF HOMEGARDENS

Structure of homegardens represents number of species present in different layers of homegardens. Kerala homegardens generally had three layers of plants. Under storey, middle storey and upper storey were the three major layers present in Kerala homegardens. Understorey consists herbs, agricultural crops, grasses etc. Middle storey contains most of the fruit trees, some timber trees, ornamental trees, shrubs etc. Upper storey comprised most of the timber trees, some of the fruit trees, palms, etc. Study was focused only on trees and agricultural crops of these layers. Middle storey of Kerala homegarden was more diverse than other two layers (Fig 26). Under storey was least diverse. Most of the favoured trees like fruit trees and medicinal trees comes in middle storey. These two functional groups were highly diverse as compared to other functional groups. Ultimately, middle storey exhibit more diversity. All three layers of large homegardens were more diverse than medium and small homegardens (Fig 27, 28 and 29). But understorey showed almost equal diversity. It was because large and medium farmers will include all possible agricultural crops in their farm. Timber, fruit trees, medicinal trees etc. were more diverse in large homegardens compared to medium and small homegardens. So the upper and middle stories were seen as more diverse in large homegardens. Interestingly, upper storey of small homegardens were less diverse than their lower storey. The less preference of

135

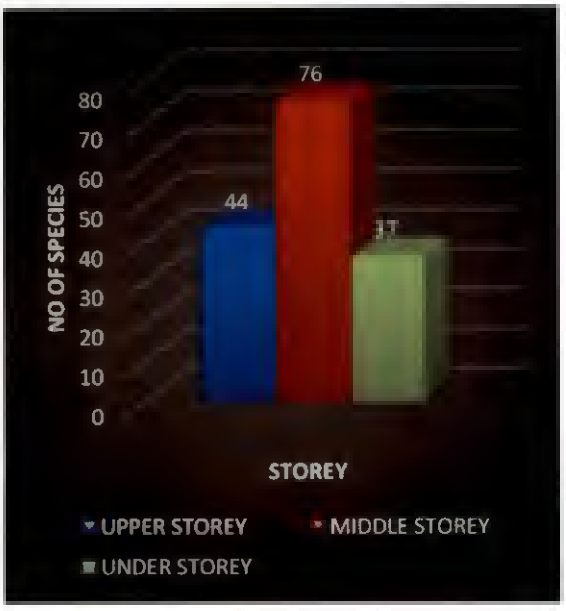

Fig 26. Number of species present in three storeys of selected total homegardens of Thrissur district, Kerala

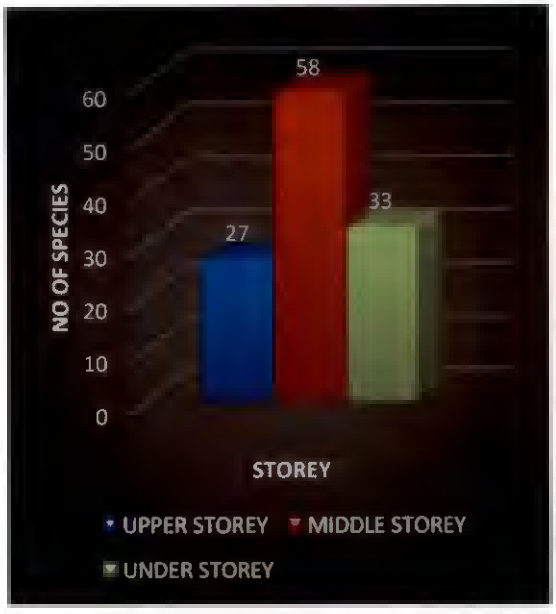

Fig 27. Number of species present in three storeys of selected small homegardens of Thrissur district, Kerala

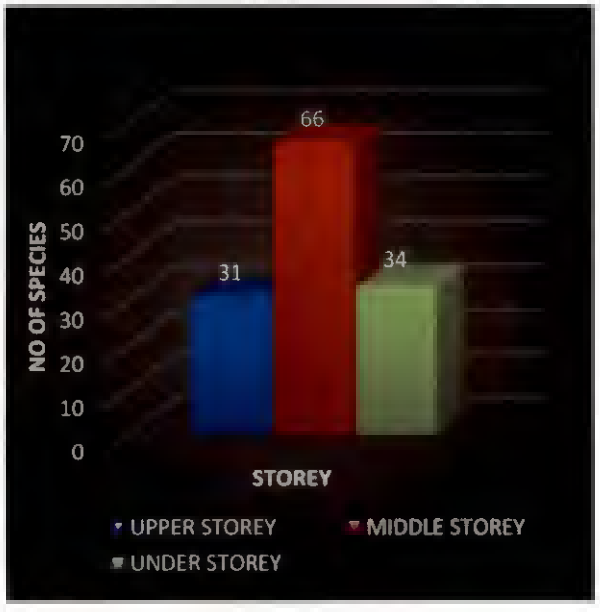

Fig 28. Number of species present in three storeys of selected medium homegardens of Thrissur district, Kerala

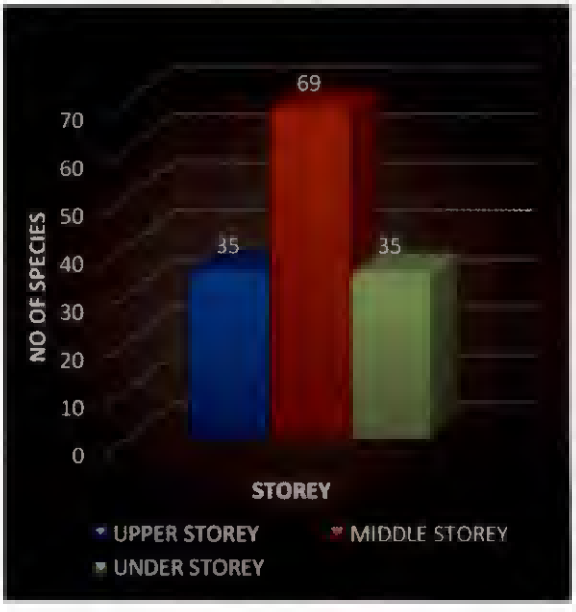

Fig 29. Number of species present in three storeys of selected large homegardens of Thrissur district, Kerala

timber and fruit trees in these gardens could be the reason for this trend. Most of the space of small homegardens was occupied by coconut palms and agricultural crops. This is a major shift compared to homegardens in other countries. For example, a study in Central Sulawesi homegardens of Indonesia identified total five strata in homegardens (Kehlenbeck and Maass, 2004). In small gardens of central Sulawesi the highest proportion of crop species occurred in the lower strata, while in large gardens it was contained in the third layer. However, the proportion of species in the upper strata was generally smaller than in the large gardens compared to small gardens in Sulawesi.

5.5 AGRICULTURE CROP DIVERSITY

Understorey agricultural crops constitute the predominant component of traditional homegardens of Kerala. They are functionally most important as they contribute substantial share to the food and nutritional security of the homegardeners. The lower strata of all homegardens around the world contain agricultural crops as the main component.

Musa sps. AAB (Palayankodan), *Areca catechu* and *Cocos nucifera* were the predominant species of all size holds (Fig 30, 31 and 32). Banana was a very common agricultural crop found in all size classes of all eco-regions. It was present in almost all selected homegardens of Thrissur district. Interestingly, arecanut was found higher than coconut in all size categories. The above structural and functional patterns and the associated species represent the common feature of most of the tropical homegardens. For instance, several studies reported coconut as the predominant component in the upper storey of homegardens. For example, study in the selected homegardens of Kerala observed that upper storey of half of the studied homegardens was dominated by coconut palms (Chandrasekhara and Baiju, 2010). However, in the present study, the abundance of coconut was not to the expected levels of reports earlier from homegardens of Kerala. Kumar *et al.* (1994) reported that about 63 % of average commercial standing volume of timber species from different taluks in Kerala state was accounted coconut palms. This decline in coconut palms could be partly

137

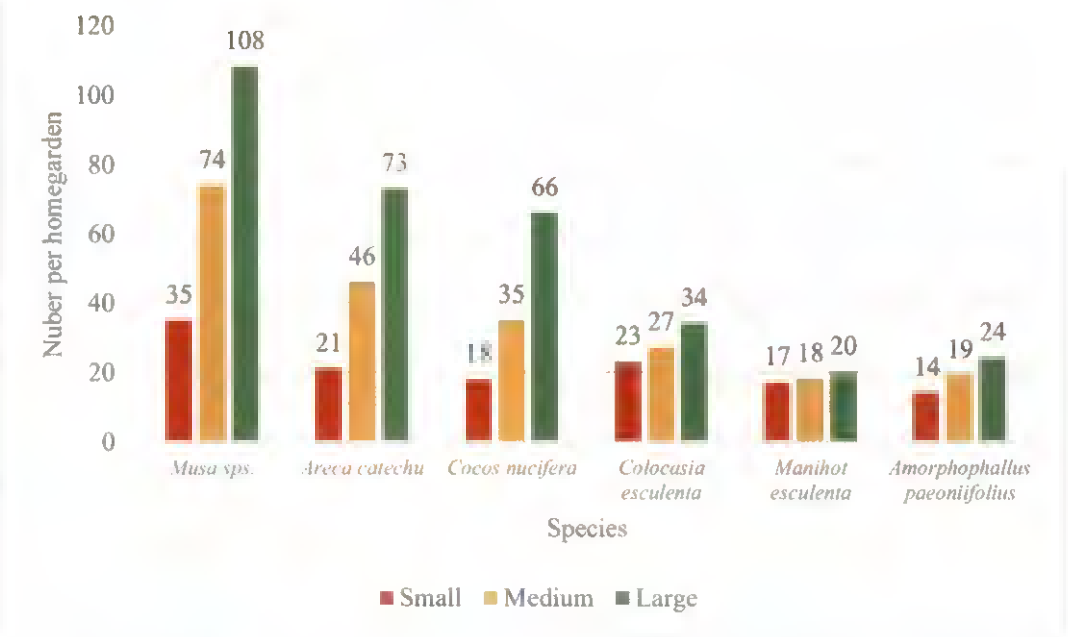

Fig 30. Average number of agricultural crop species present in varying size categories of homegardens of Thrissur district, Kerala

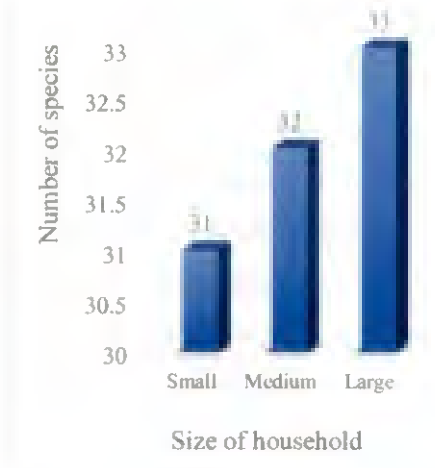

Fig 31. Total number of agricultural crop species present in varying size categories of homegardens of Thrissur district, Kerala

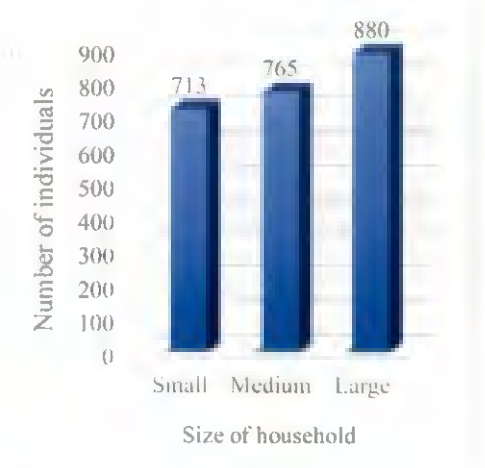

Fig 32. Abundance of each agricultural crop present in in varying size categories of homegardens of Thrissur district, Kerala

attributed to the reasons for the general decline in the state. As per the CDB, the standing coconut palms in the state are grossly under productive due to over age and unhealthy growth conditions. Pest and diseases, high maintenance cost including harvesting cost etc. deter the farmer from continuing coconut farming. Furthermore, the price fluctuation in the market turned less interest in planting or managing coconut palms. Severity of the problem was more aggravated in the coastal regions. For instance, large number of diseased and unproductive coconut palms had been removed from the homegardens of coastal area during the recent times. Panchayath itself allotting subsidies for the removal of such diseased coconut trees.

The present study could identify 37 understorey species out of 41 agricultural crops. Understorey crop diversity was fairly good as compared to many traditional homegardens of India. For example homegardens of upper Assam exhibited a rich understorey diversity of total 167 species out of 323 total species (Saikia and Khan, 2014). Whereas a study from Mizoram homegardens identified a total of 141 understorey plant species out of total 351 species which includes 42 shrub species, 94 herb species and 5 epiphytes. (Sahoo and Rocky, 2015). Yet another study from Bangladesh homegardens found a total 31 of vegetables were found to grow in association with trees either under direct shade or as creeper in homegardens (Zaman *et al.*, 2010). The above analysis of the understorey crop diversity and abundance and their relation with the garden size gives a clear indication about the changes in the overall characteristics of Kerala homegardens. For example, the understorey agricultural crop diversity was the highest in the small homegardens during older times and the diversity declined with increasing garden size. In a previous study Kumar (2011) observed that the herb diversity in the small homegardens was in the range of 20 to 77 as compared to medium (20-102) and large homegardens (17-75). Probably, the small gardens were the ones subjected to massive changes in the recent times. Improvement in the general standard of living and socio-economic status prompted the farmers to drift away from homegardening. The influence of commercialization was so intense that

they totally disregarded the homegardens for meeting their food and nutritional needs as they all available from the market without much difficulty.

Higher abundance of major agricultural crops vary according to different eco-region (Fig 33, 34 and 35). Banana, arecanut and coconut showed high preference among other crops in all eco regions. Coconut had large preference in coastal land. Because, it had better performance in coastal soil than other eco-regions. Interestingly, the studied diversity indices were higher in the peri-urban region despite its lower species diversity. This may due to the lesser number of samples in peri-urban area. A study in the homegardens of a peri-urban area of Kerala state revealed Shannon diversity index of tree species of small, medium and large homegardens were 3.87, 3.23 and 3.77 (Kunhamu *et al.*, 2015). These figures shows near values of present study.

5.6 SOCIO-ECONOMIC ANALYSIS

5.6.1 Occupation and source of income

Majority of respondents of three size categories of homegardens were pensioners (Table 47). Most of the elder family members were employees in government firms or other public sector. However, all the families surveyed had sources of income other than pension. But, overall information reveals agriculture as the main source of income (Table 49). With the acute space limitation, small holder farmers tend to refrain from agricultural practices. This is a clear indication of the changing agricultural scenario in Kerala. The high wage rate, alternative use of the land, market risks of agricultural product also add to the shift of low income group from homegardening. Earlier studies also confirmed to this changing trends in agricultural land use in Kerala (Kumar and Nair, 2004; Kumar, 2011). During older times small homegardens were rich in agricultural biodiversity as they were the main source of livelihood and nutritional security. However, with the change in the socio-economic milieu with primary income source shifting from agriculture to business and job salary, homegardening was grossly undermined. Agriculture occupation may not restrict to homegardens alone. The large space available inside the large homegarden enables farmers to

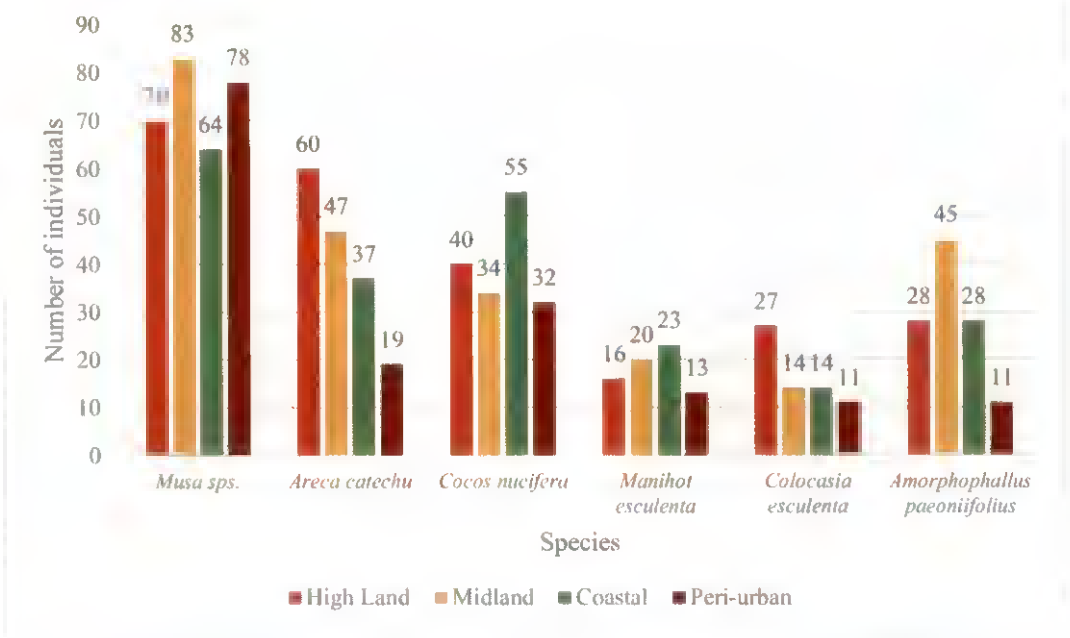

Fig 33. Average number of agricultural crop species present across different eco regions of homegardens of Thrissur district, Kerala

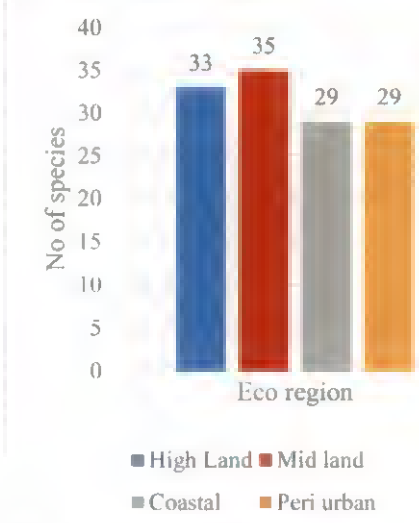

Fig 34. Total number of agricultural crop species present in different ecological regions and peri-urban area of Thrissur district, Kerala

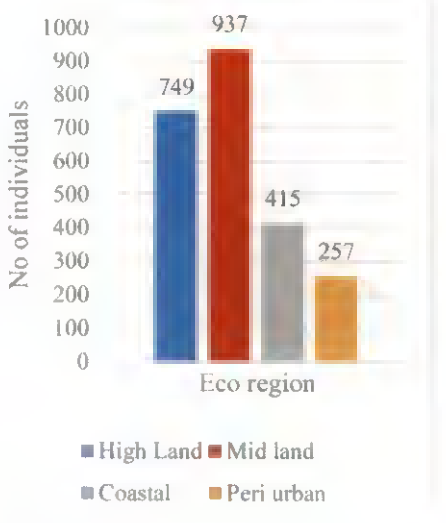

Fig 35. Abundance of each agricultural crop present in different ecological regions and peri-urban area of Thrissur district, Kerala

cultivate on a large scale. This could be the reason why large gardeners still pursue agriculture as major land use option.

Eco-region wise comparison revealed the decline in agriculture in midland and peri-urban area. In coastal area agriculture was highest is not meaning homegarden cultivation is higher. Because of poor quality soil and salt water presence farming in coastal homegardens was difficult. So they cultivate crops in outside farms or in paddy fields. Acute space limitations in peri-urban area would be the reason behind the decline in dependence on agriculture.

5.6.2 Income

It was interesting to observe that income scale was fairly high among the homegardeners. This implies that source of income may not be a major constraint in the functioning of homegardens. A closer analysis of the expenditure and income from the homegarden showed that it was proportional to the size of the gardens. As mentioned before, the income from homegardening and other agricultural sources were less in small homegardens while large homegardens provide reasonable share to their annual income. Sufficient income from such sources or lack of interest in homegardening may have influenced the poor performance of the small holder gardens.

As the large homegardens were more commercially oriented they had large level of expenditure. Availability of land and other inputs being high, their outputs were also fairly high for large homegardens and were grow with commercial objectives. Medium homegardens however, had a modest level of expenditure. Medium farmers consume most of their homegarden products and sell some products if it is available after consumption. Small farmers had very less expenditure and they consume all their homegarden products. It is important to observe that small and medium farmers had considerable loss from homegardening. They were primarily subsistence level farming with minimum commercial goals. Nevertheless, the consumption of homegarden products would certainly save considerable money from the purchase from open market. A study by Daulagala *et al.* (2013) observed the percentage income contribution of

142

homegardens of India was 0.04 % and an average contribution to the monthly income was Rs. 192.48 per month.

5.6.3 Details of livestock

The study also found that there was drastic reduction in livestock population irrespective of the homegarden size or income status (Table 53). Large homegardens faced highest drop of cattle over 15 years. Kerala homegardens enjoyed rich livestock wealth and was the strong component of the income source from the homegarden. The present alarming decline in the surveyed homegardens represent the general picture of livestock rearing in Kerala. A study from the Kalliasseri panchayat of Kannur district of Kerala state found that all livestock population declined in the recent past. Cattle population was declined around 30 % and poultry population by around 15 % between 1966 and 1992 (Sreedharan, 2004). As per the latest census report of KLDB, (2003) the present cattle population in the state is 21.22 lakh which was 33.96 lakh during 1996. Also every livestock population were declined over this period of time.

The primary reasons for the decline in livestock population in the traditional homegardens were low profit consequent to high expense for the management, scarcity of quality fodder, high cost of concentrated feed and lack of space. Small and subsistence farmers were the group involved in cattle rearing in Kerala during the earlier times. Devandra and Thomas (2002) reported that small-scale, resource-poor farmers own about 95 % of the livestock in homegardens. However, this was not visible from our study. More number of livestock in Kerala was owned by the large homegarden farmers and least owned by small farmers. Threat of stray dogs, threat of mongoose and civets, crop seed or seedling damage of own farm or of the neighbour farm etc. were some of the reasons for the poultry decline

5.6.4 Fragmentation and other constraints in homegardening

Efforts were made in the study to explore the various drivers of homegarden change. Land fragmentation was assumed to be one of the primary reason for the

143

174055

decline in the functioning of Kerala homegardens (Kumar and Nair, 2004; Kumar, 2011). Present study found that 26.4 % of surveyed homesteads undergone fragmentation. It was identified that partition was the major cause for the fragmentation of homegardens. Highest rate of fragmentation had happened in medium homegardens and in peri-urban area (Fig 36). Probable reason could be the population pressure on the land was more in the peri-urban region due to urbanization and lack of area for other developmental activities, etc. The increased population pressure may cause the higher fragmentation in midland region too. The size-wise comparison also revealed that partition was the major reason for the fragmentation of homegardens (Fig 37). It implies that partition was the most important threat that lead to the fragmentation of homegardens in Thrissur district (Fig 38 and 39). The sharp decline in the average holding size of homegardens in Kerala during the past couple of decades support our observation. The present average size of operational holdings in Kerala is 0.22 hectares (54.36 cents). During 1990-91, the average size of holding was 0.37 hectares and in 2000-01 it was 0.24 hectares (Directorate of Economics and Statistics, Kerala, 2014). The state has observed drastic decrease in area of operational holdings due to increase in demand of land for housing due to increase in its population.

Attempt was made to understand the interest of farmers in planting trees in their homegarden as a means to analyse the importance of trees in the livelihood of farmers. Majority of farmers interested in planting trees in their homegarden few farmers were not interested. There were number of reasons for the lack of interest of planting trees in their homegardens. Small farmers had a reason of less space for the planting. They maximum accommodate components required for their dietary needs. So most of them not interested in planting more trees in their garden. Some general reasons for the lack of interest of all type of farmers in planting trees were less area for planting, hindering the growth of other under storey crops and falling leaves of trees in their own premises or neighbours premises.

144

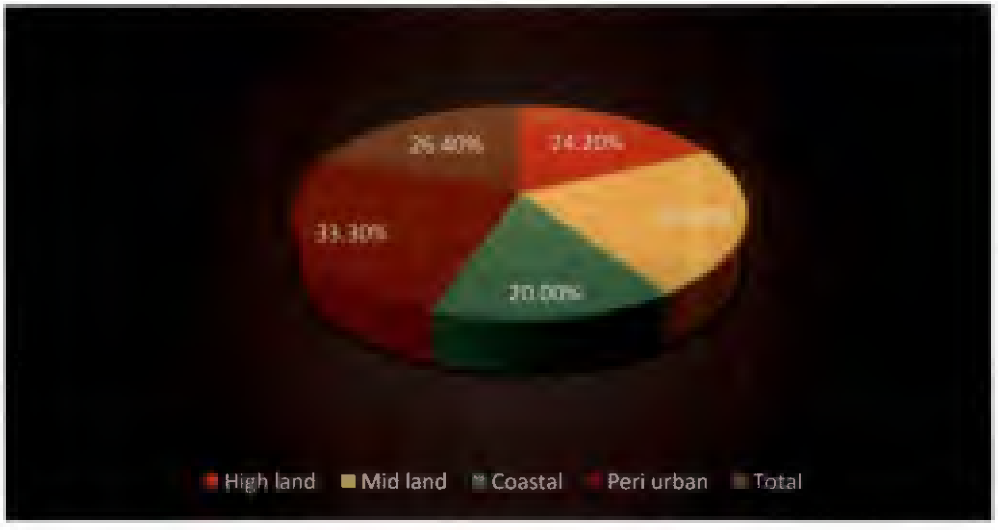

Fig 36. Frequency of fragmentation of homegardens in different eco regions of Thrissur district, Kerala

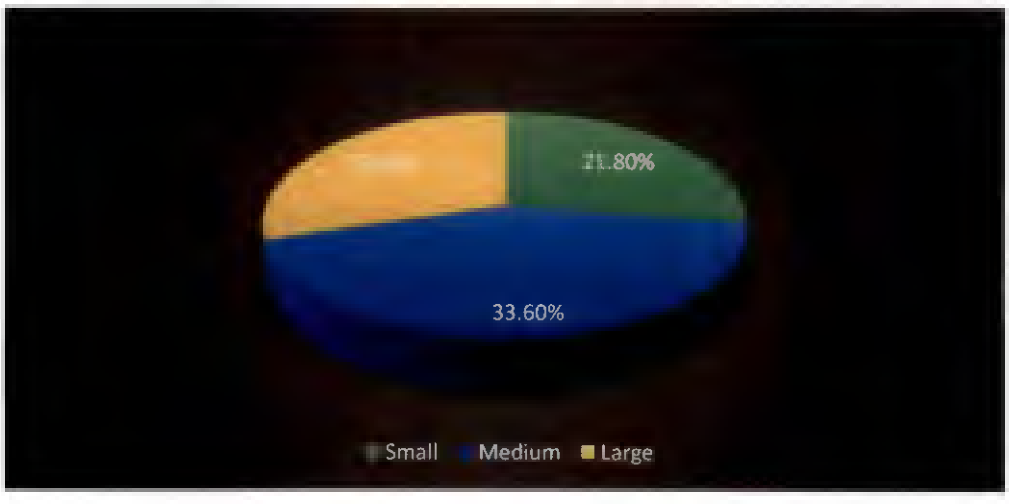

Fig 37. Frequency of fragmentation of homegardens based on size of holding of selected panchayaths of Thrissur district, Kerala

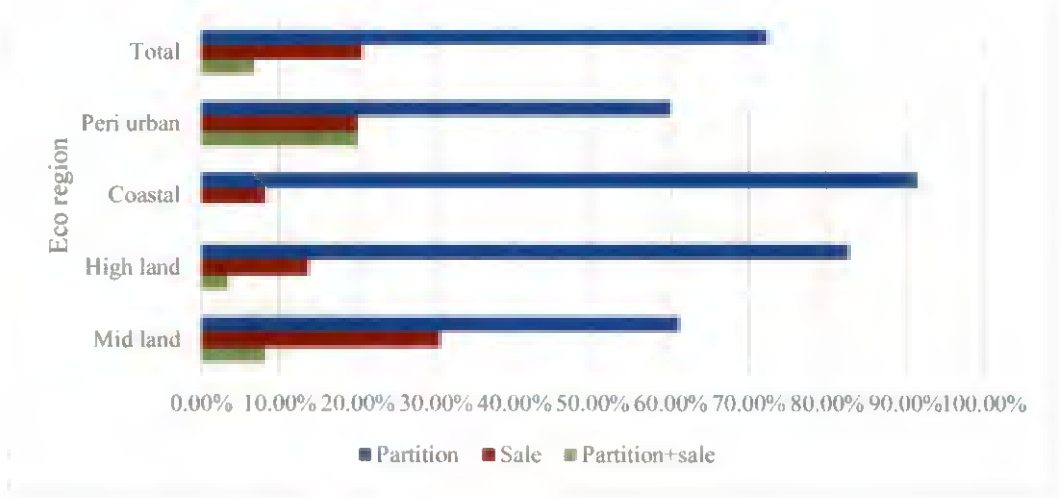

Fig 38. Causes of fragmentation of homegardens from three eco regions of Thrissur district, Kerala

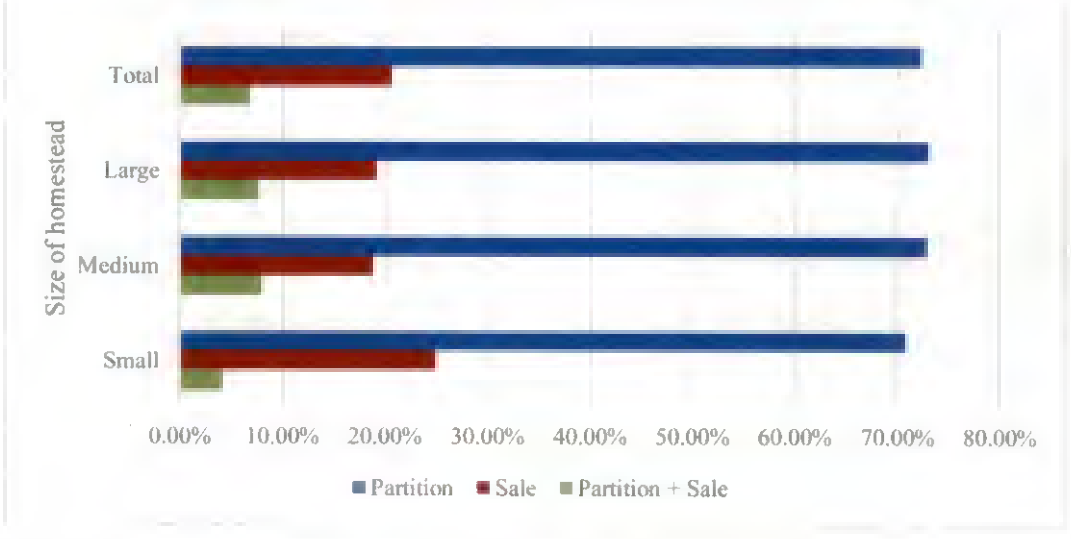

Fig 39. Causes of fragmentation based on size of holding from selected panchayaths of Thrissur district, Kerala

Majority of surveyed farmers had some type of constraints in homegardening. Very few farmers had no constraints. The most frequent response was high wage for the labourers. Kerala is having the highest wage rate in the country. The average daily wage rate for unskilled labour in the state is Rs. 700-900 which 2-3 fold as compared to other states. Large scale inflow of labour force from other states is attributed to this high wages rate. Yet another constraint in homegardening as told by the respondents is the low price of homegarden products. Hence profitable homegardening is difficult in the prevailing socio-economic fabric of Kerala.

This is particularly true for small and medium gardeners where affording labourer is almost impossible. That was the reason for less expenditure on labour charge by small farmers (Table 52). Less labour availability was also an important constraint faced by farmers especially for skilled jobs such as harvesting of coconut, arecanut, nutmeg, black pepper etc. Large expense or less profit was somehow linked with the some of the listed constraints in Table 61. The higher wage cause the high expense in homegardening and less market price of homegarden products thrashes the return from the homegarden products. Ultimately all these factors lead to the less profit making out of homegarden products marketing. Eco-region specific constraints are could be noticed in the study. For instance, Water scarcity for drinking and agricultural purpose was a major issue in the coastal regions mainly due to salt water intrusion. Less area for homegardening was the constraint specific to small homegardens (Table 63). Other constraints includes threat from animals, soil problems, no time for homegardening and lack of interest in homegardening. Threat from animals varied according to eco-region. For example, in highland wild animals like wild boar, peacock, monkey, etc. causing considerable trouble for homegarden farmers. Coconut, arecanut, tapioca, banana were the major crops that faced threat from wild animals, while in coastal land threat from crab to vegetable cultivation was a major problem. Threat from domesticated animals like hen, duck, goat etc. was a common animal threat of all eco-regions. Soil associate problems were more

147

prominent in coastal land. According to the farmers the primary cause of poor agricultural productivity was because of poor fertility of soil in the coastal regions.

5.7 WOOD QUALITY ASSESSMENT USING NON-DESTRUCTIVE TECHNIQUES

In the present study attempt has been made to examine the varaiation in wood properties for important timber species in different eco-regions. Most of the wood quality parameters showed poor variability across different eco-regions. Limited studies are available that compared the wood quality of timber trees in homegardens at different localities and also with the forest plantations. According to Bhat *et al.* (2005) teak wood cultivated in homesteads differ from forest plantation grown timber in certain characteristics such as log form, extent of natural defects, appearance or wood colour and grain as well as natural durability depending on the dry or wet locality. Nevertheless, wood density and strength properties were almost similar for all localities (Thulasidas *et al.,* 2006; Bhat *et al.*, 2004).

5.7.1 Oven dry specific gravity

Eco-region wise comparison of oven dry specific gravity ($SPG_{o.d}$) of three important timber trees reveals non-significant difference between those regions. The values obtained for *Tectona grandis* were 0.68, 0.68 and 0.69 for highland, midland and coastal land respectively. For *Artocarpus heterophyllus* it was 0.53, 0.51 and 0.53 respectively and for *Swietenia macrophylla,* values were 0.5, 0.5 and 0.49 respectively. A similar study from Thrissure, Kerala reported $SPG_{o.d}$ values of 0.68, 0.52 and 0.47 were the $SPG_{o.d}$ for *Tectona grandis, Artocarpus heterophyllus* and *Swietenia macrophylla* respectively (Ponneth *et al.,* 2014) These figures are close to the values obtained for the respective species in the present study. These values are almost constant for different eco-regions. This suggested that $SPG_{o.d}$ may not change for a specific species across different eco-region. In brief, the observations concludes that wood specific gravity, the most

148

important factor in determinant of the strength properties of wood may not vary significantly among the selected eco-regions of Thrissur.

The present study had taken four diameter classes for the comparison, 10-50, 51-100, 101-150 and 151-200 (Table 65). All these diameter classes showed no significant difference for $SPG_{o.d.}$ Similarly, in a study it was observed that wood specific gravity of 10, 15, 20 and 25 year old teak of different diameter class had similar values (Wanneng *et al.* 2014). The results were found to be contradictory to the general trend that older trees would have higher values of wood specific gravity. The study also suggested that wood properties depended not only on the growth rate of the tree but also other external environmental factors. For instance, yet another study found that both site and clone could significantly influence fibre length and specific gravity of wood (Kim *et al.*,2011). In brief detailed investigations are required to confirm the possible changes in wood specific gravity of timber grown in homegardens and plantations.

5.7.2 Dynamic Modulus of Elasticity (MOE_{dyn})

Variation of the Dynamic Modulus of Elasticity (MOE_{dyn}) or stiffness of wood according to different eco-regions was different for three timber species in the present study. Only *Tectona grandis* had non-significant difference between MOE_{dyn} values from different eco-regions. *Artocarpus heterophyllus* showed significant difference at 1 % level while *Swietenia macrophylla* had significant difference at 5 % level. The variation of MOE_{dyn} may be due to the effects of environmental or topographical or edaphic factors. MOE_{dyn} did not show variation with different girth classes. MOE_{dyn} of all species showed non-significant difference between different girth classes.

The findings were similar to the observations by Dhanya (2012) and Jiljith (2016) in teak. A study conducted by Miranda *et al.* (2011) also showed similar range of modulus of elasticity for teak obtained through destructive methods. Izekorl *et al.* (2010) observed that the mean values for MOE of 15, 20 and 25-year old *Tectona grandis* wood were 6846.92, 9920.54 and 12845.57 N mm-2

149

respectively. The study suggested that MOE increases with age, which could be attributed to increments of growth rings, and the addition of more mature wood and cambial age.

150

SUMMARY

SUMMARY

The research work entitled "*Diversity, structure and standing stock of timber in the homegardens of Thrissur district, Kerala*" was undertaken to assess the standing stock of timber trees in selected homegardens of Thrissur district. It also evaluated the present status of the homegardes in the Thrissur district in terms of diversity, structure and the various socio-economic drivers that influenced thems. Assessment involved stratified sampling of homegardens belonging to three eco-regions such as highland, midland and coastal region and three size classes viz. small, medium and large. Additionally one peri-urban area was selected for monitoring the effect of urban flux on homegarden functioning. The salient findings are summarized below:

1. Total species diversity encountered from selected homegardens of various eco-regions of Thrissur district was 163 comprises 122 tree species and 41 agricultural crop species. Interestingly, large homesteads registered highest tree species diversity with 102 species. Midland had a modest share of tree diversity with 95 species and small gardens had the lowest with 85 species.
2. Species diversity varies among different eco-regions also. Midland region displayed highest tree species diversity with 83 species. Highland recorded second highest tree species diversity with 75 species. Coastal land and peri-urban area were recorded less species diversity with 66 and 53 respectively.
3. Most abundant functional group of trees found in surveyed homegardens was timber trees with 53 species. It was followed by fruit trees (39 species), fuel trees (33 species), fodder trees (23 species), ornamental trees (16 species), medicinal trees (18 species), green manure trees (13 species) and other use trees (15).
4. Highest diversity was recorded from Panjal panchayath located in highland region with 72 species. One of the coastal panchayath Orumanayur registered the lowest species diversity with 49 species.

152

5. Total number per hectare of timber species in Thrissur district was 42 no/ha and projected number of all timber species was estimated as 62,44,770. *Mangifera indica* topped in terms of abundance with 11 number per hectare and 15,98,849 estimated of individuals present in whole Thrissur district. *Tectona grandis* and *Artocarpus heterophyllus* had almost similar abundance of 6 and 7 per ha respectively. Their projected abundance were 17,77,939 and 19,76,086 numbers respectively.
6. *Mangifera indica* showed more abundance in the coastal region as compared to other regions. *Tectona grandis* and *Artocarpus heterophyllus* were more in midland region. *Swietenia macrophylla* and *Artocarpus hirsutus* also showed better count in the coastal region when computed on per ha basis.
7. Trees, agricultural crops and medicinal plants were the prominent constituents of different layers of homegardens. Middle storey of all three size classes displayed higher number of species. Large homegardens showed higher number of species in all three layers. Least species diversity was observed in upper storey of small homegardens.
8. Standing stock per hectare of total timber species in Thrissur district was estimated as 55.12 m^3 ha^{-1} and projected standing stock of all timber species was 81,38,931.6 m^3.
9. *Mangifera indica* was the leading species in the list in terms of standing stock with 12.76 m^3 ha^{-1} and 18,84,356.3 m^3 projected standing stock in whole Thrissur district. The projected standing stock of *Tectona grandis* and *Artocarpus heterophyllus* were 15,71,871.9 m^3 and 14,77,224.5 m^3 respectively.
10. Standing stock per hectare of important timber species varies among different eco-regions. Highland had highest standing stock per hectare of timber species (63.3 m^3 ha^{-1}) followed by midland (61.4 m^3 ha^{-1}), peri-urban region (47.6 m^3 ha^{-1}) and coastal land (33 m^3 ha^{-1}).
11. Standing stock of timber species vary according to the size categories of homegardens of Thrissur district. Highest share of standing stock of timber species was in medium homegardens (63 m^3 ha^{-1}). Large gardens registered

153

modest share of standing stock (55.2 m^3 ha^{-1}) while small gardens had the least (46.4 m^3 ha^{-1}).

12. Banana (*Musa sps.* AAB (Palayankodan)) was the predominant agricultural crop in all the size categories followed by arecanut (*Areca catechu)*, coconut (*Cocos nucifera),* colocasia (*Colocasia esculenta), cassava (Manihot esculenta) and* elephant foot yam *(Amorphophallus paeoniifolius).*
13. Shannon Wiener Index and Simpson Diversity Index were highest for large homegardens which were in the order of 3.08 and 0.94 respectively. These indices were lowest for small homegardens and the respective values were 2.92, and 0.93.
14. Based on socio-economic survey general perception among the 330 homegardens surveyed suggest that aged pensioners run the homegardens (22.7%). But, overall information reveals agriculture as the main source of income.
15. Income scale of was fairly high among the homegardeners. This implies that source of income may not be a major constraint in the functioning of homegardens.
16. A comparison of the total income from home garden and expenditure for home garden gives that small and medium home gardens are non-profitable. Profit only observed for large homesteads
17. All size classes of homegardens spent more money for labour charge (mean Rs. 8587.4). Highest expenditure for labour charge was observed for large homegardens (Rs. 18,076.5) and small homegarden farmers managed to restrict the expenditure for labour charge at a lower level (Rs. 3309.9).
18. All size categories displayed decrease in total number of livestock by 15 years. During 1990s number of cattle was 407 and it substantially decreased to 148 by 2015.
19. Out of 330 homegardens surveyed 87 were fragmented (26.4%) and partition is identified as the major reason for the fragmentation. Highest rate of fragmentation had happened in medium homegardens and in peri-urban area.

154

20. Out of 330 respondents 233 (70.6%) were interested in planting trees in their homestead. But 97 (29.4%) were not interested in planting trees in their premises.
21. Majority of respondents suggested high wage as their major constraint in homegardening. Less labour availability was another major constraint followed by large expense, pest and disease, water scarcity, less area for homegardening.
22. Oven dry specific gravity ($SPG_{o.d}$) of three major timber species assessed. *Tectona grandis*, *Artocarpus heterophyllus* and *Swietenia macrophylla* had non-significant difference of $SPG_{o.d}$ across all three eco-regions and also between four girth classes such as 10-50, 51-100, 101-150 and 151 to 200 cm.
23. *Tectona grandis* did not have a significant difference of MOE_{dyn} between eco-regions. But, *Artocarpus heterophyllus* and *Swietenia macrophylla* showed significant difference between three eco-regions.
24. Over all the study converges to the conclusion that Kerala homegardens despite all socio-economic and demographic adversities maintain fair status in terms of species diversity and standing stock. However there is genuine need of conserted efforts to revitalize these unique land use systems for maintaining their economic vaiability with out compromising their ecological and social dimensions.

155

REFERENCES

REFERENCES

Abdoellah, O.S. 1990. Homegardens in Java and their future development. In: Landauer, K. and Brazil, M. (eds), *Tropical home gardens*, United Nations University Press, Tokyo, pp. 69-79.

Abdoellah, O.S., Hadikusumah, H.Y., Takeuchi, K., Okubo, S. and Parikesit. 2006. Commercialization of homegardens in an Indonesian village: vegetation composition and functional changes. *Agrofor. Syst.* 68(1): 1-13.

Abebe, T. 2005. Diversity in homegarden agroforestry systems of Southern Ethiopia. PhD thesis, Wageningen University, Wageningen, 143p.

Abebe, T., Wiersum, K.F., Bongers, F., and Sterck, F. 2006. Diversity and dynamics in homegardens of southern Ethiopia. In: Kumar, B.M. and Nair P.K.R. (eds), *Tropical homegardens: A time-tested example of sustainable agroforestry*. Springer Science, Dordrecht, pp. 123-142.

Agelet, A., Angels, B.M., and Valles, J. 2000. Homegardens and their role as a main source of medicinal plants in mountain regions of Catalonia (Iberian peninsula). *Econ. Bot.* 54: 295-309.

Alam, M. 2011. Tropical homegardens in Bangladesh: characteristics and sustainability. In: Lichtfouse, E. and Dordrecht. (eds), *Alternative Farming Systems, Biotechnology, Drought Stress and Ecological Fertilisation*, Sustainable Agriculture Reviews 6: The Netherlands, Springer Science, pp. 245-262

Altieri, M.A. 1999. The ecological role of biodiversity in agroecosystems. *Agric. Ecosyst. Environ.* 74:19-31.

Babu, K.S., Jose, D., and Gokulapalan, C. 1982. Species diversity in a Kerala home garden. *Agrofor. Today.* 4:15-20.

Beer, J., Muschler, R., Kass, D., and Somarriba, E. 1998. Shade management in coffee and cacao plantations. *Agrofor. Syst.* 38: 139-164.

Bhat, K. M. and Priya, P. B. 2004. Influence of provenance variation on wood properties of teak from the Western Ghats region in India. *IAWA J.* 25 (3): 273-282.

Bhat, K.M., Thulasidas, P.K., Florence, E.J.L., and Jayaraman, K. 2005. Wood durability of home-garden teak against brown-rot and white-rot fungi. *Trees,* 19:654-660.

Blanckaert, I., Swennen, R., Floresa, P.M., Rosas, R., Lopez, L., and Saade, L.R. 2004. Floristic composition, plant uses and management practices in homegardens of San Rafael Coxcatlan, Valley of Tehuacan-Cuicatlan, Mexico. *J. Arid Environ.* 57:39-62.

Calvet-Mir, L., Gómez-Baggethun, E., and Reyes-García, V. 2012. Beyond food production: Ecosystem services provided by home gardens. A case study in Vall Fosca, Catalan Pyrenees, Northeastern Spain. *Ecol. Econ.*74: 153-160.

Chandrashekara, U.M. 1995. Ecological and economic benefits of tree components in homestead farming systems of Kerala. In: Pillai, P.P. and Nair, R.P. (eds), *Understanding Ecologically Sustainable Economic Development.* Institute of Planning and Applied Economic Research, Dr. John Mathai Centre, Thrissur, pp. 104-108.

Chandrashekara, U.M. and Baiju. 2010. Changing pattern of species composition and species utilization in homegardens of Kerala, India. *Trop. Ecol.* 51(2): 221-233.

Cromwell, E., Cooper, D., and Mulvany, P. 1999. *Agriculture, biodiversity and livelihoods: Issues and entry points for development agencies.* Overseas Development Institute, London, 69p.

Daulagala, C., Weerahewa, J., Marambe, B., Pushpakumara, G., Silva, P., Punyawardena, R., Premalal, S., Miah, G., Roy, J., and Jana, S. 2013. Socio-economic characteristics of farmers influencing adaptation to climate change: empirical results from selected home gardens in South Asia with emphasis on commercial orientation. *Sri Lanka J. Advanced Social Studies.* 2: 71-90.

De-La-Cerda, H.E.C. and Mukul, R.R.G. 2008. Homegarden production and productivity in a Mayan community of Yucatan. *Hum. Ecol.* 36: 423-433.

Department of Economics and Statistics. 2014. *Report on 9th agricultural census* 2010-2011. Department of Economics and Statistics, Thiruvananthapuram, 88p.

Devendra, C. and Thomas, T. 2002. Crop-animal systems in Asia: Importance of livestock and characterization of agro-ecological zones. *Agric. Syst.* 71: 5-15.

Devi, N.L. and Das, A.K. 2013. Diversity and utilization of tree species in Meitei homegardens of Barak Valley, Assam. *J. Environ. Biol.* 34: 211-217.

Dhanya, P. 2012. Destructive and non-destructive evaluation of wood properties in selected timbers of Kerala. MSc (For) thesis, Kerala Agricultural University, Thrissur. 83p.

EARP [East Asia Research Programme]. 2015. EARP home page [online]. Available: http://earp.in/en/india-in-the-cop21-on-climate-change-paris-november-december-2015 [29 December 2016].

Ewel, J.J. 1999. Natural systems as models for the design of sustainable systems of land use. *Agrofor. Syst.* 45: 1–21.

Fassbender, H.W., Beer, J., Heuveldop, J., Imbach, A., Enriquez, G., and Bonnemann, A. 1991. Ten year balances of organic matter and nutrients in agroforestry systems at CATIE, Costa Rica. *For. Ecol. Manag.* 45: 173-183.

159

Fernandes, E.C.M. and Nair, P.K.R. 1986. An evaluation of the structure and function of tropical homegardens. *Agric. Syst.* 21: 279-310.

FSI [Forest Survey of India]. 2015. FSI home page [online]. Available: http://www.fsi.nic.in. [03 January 2017].

Gajaseni, J. and Gajaseni, N. 1999. Ecological rationalities of the traditional homegarden system in the Chao Phraya Basin Thailand. *Agrofor. Syst.* 46:3-23.

Gautam, R., Suwal, R. and Shrestha, P.K. 2004. Status of home gardens of Nepal: Findings of baseline survey conducted in four sites of home garden project. In: Gautam, R., Sthapit, B.R., and Shrestha, P.K. (eds), *Home Gardens in Nepal*. Proceedings of workshop on Enhancing the contribution of home garden to on-farm management of plant genetic resources and to improve the livelihoods of Nepalese farmers: lessons learned and policy implications, 6–7 August 2004, Pokhara, Nepal. LI-BIRD, Bioversity International and SDC, Rome, Italy, pp. 72-83

Gebauer, J. 2005. Plant species diversity of home gardens in El Obeid, Central Sudan. *J. Agric. Rural Dev. Trop. Subtrop.* 106:97-103.

Haque, S.A. 2006. Salinity problems and crop production in coastal regions of Bangladesh. *Pakistan J. Bot.* 38: 1359-1365.

Heywood, V.H. and Watson, R.T. 1995. Global biodiversity assessment. Cambridge University Press, Cambridge. 1140p.

Isaac, S.R. and Nair, M.A. 2006. Litter dynamics of six multipurpose trees in a homegarden in southern Kerala India. *Agrofor. Syst.* 67:203-213.

Izekor, D.N., Fuwape, J.A., and Oluyege, A. O. 2010.Effects of density on variations in the mechanical properties of plantation grown *Tectona grandis* wood. *Arch. Appl. Sci. Res.* 2 (6):113-120.

160

Jackson, L.E., Pascual, U., and Hodgkin, T. 2007. Utilizing and conserving agrobiodiversity in agricultural landscapes. *Agric. Ecosyst. Environ.* 121: 196-210.

Jaman, M.S., Hossain, M.F., Islam, M.S., Helal, M.G.J., and Jamil, M. 2016. Quantification of Carbon Stock and Tree Diversity of Homegardens in Rangpur District, Bangladesh. *Int. J. Agric. For.* 6(5): 169-180.

Jiljith, K. P. 2016. Genetic variation in wood basic density and MOE and their relationship with growth traits in teak (*Tectona grandis* L.f) grown in seed orchards of Kerala. M.Sc. (For) thesis, Kerala Agricultural University, Thrissur, 80p.

John, J. 2014. Homestead Farming in Kerala: A Multi-Faceted Land-Use System. *Rev. Agrarian Stud.* 4(1). Available: http://ras.org.in/homestead_farming_in_kerala. [15 March 2017].

Johnson-Welch, C., Alemu, B., Msaki, T. P., Sengendo, M., Kigutha, H., and Wolff, A. 2000. Improving household food security; institution, Gender and Integrated approaches. Land Tenure Centre, Madison, 57p.

Karyono. 1990. Homegardens in Java; their structure and function. In: Landauer, K. and Brazil, M. (eds), *Tropical Homegardens*, United Nations University Press, Tokyo, pp. 138-146.

Kehlenbeck, K. and Maass, B.L. 2004. Crop diversity and classification of homegardens in Central Sulawesi, Indonesia. *Agrofor. Syst.* 63(1): 53-62.

Kehlenbeck, K., Arifin, H.S., and Maass, B.L. 2007. Plant diversity in homegardens in a socio-economic and agro-ecological context. In:.Tscharntke, T., Leuschner, C., Zeller, M., Guhadja, E., and Bidin, A. *The Stability of Tropical Rainforest Margins, Linking Ecological, Economic and Social Constraints of Land Use and Conservation*, Environmental Science Series, Springer Verlag, Berlin. pp. 297-319.

161

Kim, N. T., Matsumura, J., and Oda, K. 2011. Effect of growing site on the fundamental wood properties of natural hybrid clones of *Acacia* in Vietnam. *Wood Sci.* 57: 87-93.

Klausner, W.J. 1960. The Northeast migration problem. In Social Service in Thailand. Department of Public Welfare, Thai Ministry of Interior, Bangkok, pp. 125-38.

KLDB [Kerala Livestock Development Board]. 2003. KLDB home page (on-line). Available: www.livestock.kerala.gov.in. [29 March 2017].

Krishnankutty, C. N. 1990. *Demand and supply of wood in Kerala and their future trends*. Research Report 67. Kerala Forest Research Institute, Peechi, 66p.

Krishnankutty, C. N. and Chundamannil, M. 2012. *Timber supply situation in Kerala: projection for the year 2010-11*. KFRI Research Report No. 426, Kerala Forest Research Institute, Peechi, India, 26p.

Krishnankutty, C.N., Thampi, K.B., and Chundamannil, M. 2005. Wood-balance study in Kerala and market survey. KFRI Research Report No. 268, Kerala Forest Research Institute, Peechi, 54p.

Kumar, B. M. 2006a. Carbon sequestration potential of tropical homegardens. In: Kumar, B. M. and Nair, P. K. R. (eds.), *Tropical Homegardens: A Time-Tested Example of Sustainable Agro- forestry*. Advances in Agroforestry, No.3, Springer, Dordrecht, Netherlands, pp. 185-204.

Kumar, B.M. 2006b. Agroforestry: the new old paradigm for Asian food security. *J. Trop. Agric* 44:1-14

Kumar, B.M. 2008. Assessment of standing stock of thorny bamboo [*Bambusa bambos* (L.) Voss] in the homegardens of Palakkad and Malappuram districts in Kerala. *J. Trop. Agric*. 46 (1-2): 32-37.

Kumar, B.M. 2011. Species richness and aboveground carbon stocks in the homegardens of central Kerala, India. *Agric. Ecosyst. Environ.* 140: 430-440.

Kumar, B.M. and Nair P.K.R. 2004. The enigma of tropical homegardens. *Agrofor. Syst.* 61: 135-152.

Kumar, B.M., George, S.J., and Chinnamani, S. 1994. Diversity, structure and standing stock of wood in the home gardens of Kerala in Peninsular India. *Agrofor. Syst.* 25 (3): 243-262.

Kumar, B.M., Sudheesh, K.G., and Rajesh, G. 2005. Standing stock of thorny bamboo [*Bambusa bambos* (L.) Voss] in the homegardens of Thrissur, Kerala. *J. Trop. Agric.* 43: 61-66.

Kunhamu, T.K., Ajeesh, R., and Kumar, V. 2015. Floristic Analysis of Peri-Urban Homegardens of Southern Kerala, India. *Indian J. Ecol.* 42(2): 300-305.

Landauer, K., and Brazil, M. 1990. *Tropical Homegardens*. United Nations University, Tokyo, 257p.

Levasseur, V. and Olivier, A. 2000. The farming system and traditional agroforestry systems in the Maya community of San Jose, Belize. *Agrofor. Syst.* 49: 275-288.

McNeely, J.A. and Schroth, G. 2006. Agroforestry and biodiversity conservation–traditional practices, present dynamics and lessons for the future. *Biodivers. Conserv.* 15:549-554.

Miranda, I., Sousa V., and Pereira, H. 2011. Wood properties of teak (*Tectona grandis*) from a mature unmanaged stand in East Timor. *J. Wood Sci.* 57:171-178

Mohan, S. 2004. An assessment of the ecological and socio-economic benefits provided by home gardens: a case study of Kerala, India. PhD thesis, University of Florida, Gainsville, 120p.

163

Molina, M.R., Noguera, A., Dary, O., Chew, F., and Valverde, C. 1993. Principal micronutrient deficiencies in Central America. *Food Nutr. Agric.* 7: 26-33.

Montagnini, F. and Nair, P. K. R. 2004. Carbon sequestration: An underexploited environmental benefit of agroforestry systems. *Agrofor. Syst.* 61–62: 281-295.

Nair, M.A. and Sreedharan, C. 1986. Agroforestry farming systems in the homesteads of Kerala, Southern India. *Agrofor. Syst.* 4: 339-363.

Nair, P.K.R. 1993. *An Introduction to Agroforestry*. Kluwer, Dordrecht, 499p.

Nair, P.K.R. 2001. Do tropical homegardens elude Science, or it is the other way around. *Agrofo.r Syst.* 53: 239-245.

Nair, P.K.R., and Kumar, B.M. 2006. Introduction. In: Kumar, B.M. and P.K. Nair (eds.). *Tropical Homegardens: A time-tested example of Sustainable Agroforestry*. Springer, Dordrecht, pp. 1-10.

Nair, P.K.R., Kumar, B.M., and Vimala, D. N. 2009. Agroforestry as a strategy for carbon sequestration. *J. Plant Nutr. Soil Sci.* 172: 10-23.

Ninez, V.K. 1985.Working at half-potential: constructive analysis of homegarden programme in the Lima slums with suggestions for an alternative approach. *Food Nutr. Bull.* 7 (3): 6-13.

Ninez, V.K. 1987. Household gardens: theoretical considerations on an old survival strategy. *Agric. Syst.* 23: 167-186.

Okigbo, B. 1990. Home Gardens in Tropical Africa. In: Landauer, K. and Brazil, M. (eds). *Tropical Home Gardens.* United Nations University Press, Tokyo, 344p.

Pandey, C.B., Lata, K., Venkatesh, A. and Medhi, R.P. 2006. Diversity and species structure of home gardens in South Andaman. *Trop. Ecol.* 47(2): 251-258.

164

Perera, A.H. and Rajapakse, R.M.N. 1991. A baseline study of Kandyan forest gardens of Sri Lanka: structure, composition and utilization. *For. Ecol. Manage*. 45: 269-280.

Perrault-Archambault, M. and Coomes, O.T. 2008. Distribution of agrobiodiversity in home gardens along the Corrientes River, Peruvian Amazon. *Econ Bot.* 62 (2): 109-126.

Peyre, A., Guidal, A., Wiersum, K.F. and F. Bongers. 2006. Homegarden dynamics in Kerala, India. In: Kumar B.M. and Nair P.K.R. (eds), *Tropical homegardens: A time-tested example of sustainable agroforestry*. Springer, Netherlands, pp.87-103.

Ponneth, D., Anoop, E.V, Easwaran, J.C., Mohandass, A. and Chauhan, S.S. 2014. Destructive and non-destructive evaluation of seven hardwoods and analysis of data correlation. *Holzforschung*, 68(8): 951-956.

Ranasinghe, T.T. 2009. *Manual of Low/No-Space Agriculture cum-Family Business Gardens.* Leusden, Netherlands: RUAF Foundation, 110p.

Rao M.R., Schroth G., Williams S., Namirembe S., Schaller M., Wilson J., and Vandermeer J. 2004. Managing belowground interactions in agroecosystems. In: van Noordwijk. M., Cadisch G., and Ong C.K. (eds), *Belowground Interactions in Multiple Agroecosystems*. CAB International, Wallingford, pp. 29-35.

Rao, M.R. and Rao, B.R.R. 2006. Medicinal plants in tropical homegardens. In: Kumar, B.M. and Nair, P.K.R. (eds.), Tropical Homegardens: A Time Tested Example of Sustainable Agroforestry, pp. 205-232.

Rico-Gray, V., Chemas, A., and Mandujano, S. 1991. Use of tropical deciduous forest species by the Yucatan Maya. *Agrofor. Syst.* 14: 149-161.

Roshetko, M., Delaney, M., Hairiah, K., and Purnomosidhi, P. 2002. Carbon stocks in Indonesian homegarden systems: Can smallholder systems be targeted for increased carbon storage? *Am. J. Alt. Agric.* 17: 125 -137.

Rugalema, G.H., Johnsen, F.H., and Rugambisa, J. 1994. The homegarden agroforest system to Bukoba district, North-Western Tanzania.2. Constraints to farm productivity. *Agrofor. Syst.* 26: 205–214.

Saha, S.K., Nair, P.K., Nair, R., Kumar, V.D., and Mohan, B. 2010. Carbon storage in relation to soil size-fractions under tree-based land-use systems. *Plant Soil* 328:433-446.

Saha, S. K., Nair, P. K. R., and Nair, V. D. 2009. Soil carbon stock in relation to plant diversity in homegarden systems in Kerala, India. *Agroforestry Syst.* 76: 53–65.

Sahoo, U.K. and Rocky, P. 2015. Species composition and plant diversity as influenced by altitude and size of homegardens in Mizoram, north-east India. *International J. Ecol. Environ. Sci.* 41(3-4): 195-215.

Sahoo, U.K., Rocky, P., Vanlalhriatpuia, K., and Upadhyaya, K. 2010. Structural diversity and functional dynamism of traditional home gardens of North-East India. The Bioscan. 1: 159-171.

Saikia, P. and Khan, M.L. 2014. Homegardens of upper Assam, northeast India: a typical example of on farm conservation of Agarwood (*Aquilaria malaccensis* Lam.). *Int. J. Biodivers. Sci. Ecosyst. Serv. Manag.* 10(4): 262-269.

Sandhu, H.S., Wratten, S.D., and Cullen, R. 2010. The role of supporting ecosystem services in conventional and organic arable farmland. *Ecol. Comp.* 7: 302-310.

Shanavas, A. and Kumar, B.M. 2003. Fuelwood characteristics of tree species in the homegardens of Kerala, India. *Agrofor. Syst.* 58:11-24.

166

Shastri, C. M., Bhat, D. M., Nagaraja, B. C., Murali, K. S., and Ravindranath, N. H. 2002. Tree species diversity in a village ecosystem in Uttara Kannada district in Western Ghats, Karnataka. *Curr. Sci.* 82 (9): 1080-1084.

Shrestha, P., Gautam, R., Rana, R.B. and Sthapit, B.R. 2002. Home gardens in Nepal: status and scope for research and development. In: Watson, J.W. and Eyzaguirre, P. B. (eds). Home gardens and in situ conservation of plant genetic resources in farming systems, 17-19, July, 2001, Witzenhausen, Germany/IPGRI, Rome, pp. 105-124.

Singh, G. B. 1987. Agroforestry in the Indian subcontinent: past, present and future. In: Steppler, H. A. and Nair, P.K.R (eds), *Agroforestry: A Decade of Development*. ICRAF, Nairobi, pp. 117-140.

Soemarwoto, O. 1987. Home gardens: a traditional agroforestry system with a promising future. In: Steppler, H.A. and. Nair, P.K.R. (eds.) *Agroforestry: A Decade of Development*. ICRAF, Nairobi, pp. 157-172.

Soemarwoto, O. and Conway, G.R. 1991. The Javanese homegarden. *J. Farming Syst. Res. Ext.* 2(3): 95-117.

Sreedharan, T.P. 2004. *Biological Diversity of Kerala: A survey of Kalliasseri panchayat, Kannur district*. Centre for Development Studies, Prasanth Nagar, 176p.

Subedi, A., Suwal, R., Gautam, R., Sunwar, S., and Shrestha, P. 2006. Status and composition of plant genetic diversity in Nepalese home gardens. In: Gautam, R., Sthapit, B.R., and Shrestha, P.K. (eds), *Home Gardens in Nepal*. Proceedings of workshop on Enhancing the contribution of home garden to on-farm management of plant genetic resources and to improve the livelihoods of Nepalese farmers: lessons learned and policy implications, 6-7 August 2004, Pokhara, Nepal. LI-BIRD, Bioversity International and SDC, Rome, Italy, pp. 72-83.

Sunwar, S. 2003. *Understanding the plant diversity and its contribution to on-farm conservation of plant genetic resources in home gardens of Nepalese farming systems.* MSc thesis, The Swedish Biodiversity Centre (CBM), Uppsala, Sweden. 41p.

Suprayogo, D. 2000. Testing the Safety-net of Hypothesis in Hedgerow Intercropping water balance and Mineral N-Leaching in the Humid Tropics. PhD thesis, University of London, London, 315p.

Swift, M.J. and Anderson, J.M. 1993. Biodiversity and ecosystem function in agricultural systems. In: Schulze, E-D, and Mooney, H.A. (eds.), *Biodiversity and Ecosystem Function*. Berlin: Springer-Verla, pp. 15-41.

Swinton, S. M., Lupi, F., Robertson, G. P., and Hamilton, S. K. 2007. Ecosystem services and agriculture: cultivating agricultural ecosystems for diverse benefits. *Ecol. Econ.* 64: 245-252.

The Directorate of Economics & Statistics. 2011. The Directorate of Economics & Statistics home page [on line]. Available: www.ecostat.kerala.gov.in. [05 February 2017].

Thulasidas, P. K., Bhat, K. M., and Okuyama, T. 2006. Heartwood colour variation in home garden teak (*Tectona grandis*) from wet and dry localities of Kerala, India. *J. Trop. For. Sci.* 18(1): 51-54.

Tolera, M., Asfaw, Z., Lemenih, M., and Karltun, E. 2008. Woody species diversity in a changing landscape in the south-central highlands of Ethiopia. *Agric. Ecosyst. Environ.* 128: 52-58.

Torquebiau, E. 1992. Are tropical agroforestry homegardens sustainable? *Agric. Ecosyst . Environ.* 41: 189-207.

Trinh, L.N., Hue, N.T.N., De, N.N., Minh, N.V., and Chu, P.T. 2002. Role of home gardens in the conservation of plant genetic resources in Vietnam. In: Watson, J.W. and Eyzaguirre, P.B. (eds), *Home gardens and in situ*

conservation of plant genetic resources in farming systems. Proceedings of the second international home garden workshop, 17-19 July, Witzenhasen, Germany. DSE/ZEL, GTZ, IPGRI, pp. 97-104.

Trinh, L.N., Watson, J.W., Hue, N.N., De, N.N., Minh, N.V., Chu, P., Sthapit, B.R., and Eyzaguirre, P.B. 2003. Agrobiodiversity conservation and development in Vietnamese home gardens. *Agric. Ecosyst. Environ.* 97: 317-344.

UNFCCC [United Nations Framework Convention on Climate Change]. 2015. UNFCCC home page [online]. Available: http://unfccc.int/paris_agreement/items/9485.php. [26 December 2016].

Vogl, C.R., Vogl-Lukasser, B.N. and Caballero, J. 2002. Homegardens of Maya migrants in the district of Palenque, Chiapas, Mexico. Implications for sustainable rural development. In: Stepp, J.R., Wyndham, F.S., and Zarger, R.K. (eds.). Ethnobiology and Biocultural Diversity. University of Georgia Press, Athens, USA, pp. 631-647.

Wanneng, P. X., Ozarska, B., and Daian, M. S. 2014. Physical properties of *Tectona grandis* grown in laos. *J. Trop. For. Sci.* 26(3): 389-396.

Watson, J.W. and Eyzaguirre, P.B. (eds.) 2002. Home Gardens and In Situ Conservation of Plant Genetic Resources in Farming Systems. *Proceedings of the Second International Home Gardens Workshop*, 17-19 July 2001, Witzenhausen, Germany. IPGRI, Rome, Italy, pp. 184

Wickramasinghe, A. 1996. The non-forest wood fuel resources of Sri Lanka. *Wood Energy News* 11: 14-18.

Wiersum, K.F. 1982. Tree gardening and taungya on Java: examples of agroforestry techniques in the humid tropics. *Agrofor. Syst.* 1: 53-70.

Wiersum, K.F. 1995. 200 years of sustainability in forestry: lessons from history. *Environ. Manage.* 19: 321-32.

Wiersum, K.F. 2006. Diversity and change in homegarden cultivation in Indonesia. In: Kumar, B.M. and Nair, P.K.R. (eds), *Tropical homegardens: A time-tested example of sustainable agroforestry*, Springer Science, Dordrecht, pp. 13-24.

Wilson, R.T. 1995. Livestock Production Systems. London, UK: Macmillan, 365p.

Zaman, S., Siddiquee, S.U., and Katoh, M. 2010. Structure and diversity of homegarden agroforestry in Thakurgaon District, Bangladesh. *Open. For. Sci. J.* 3:38-44

Zhang, W., Ricketts, T. H., Kremen, C., Carney, K., and Swinton, S. M. 2007. Ecosystem services and dis-services to agriculture. *Ecol. Econ.* 64: 253-260.

170

APPENDIX

APPENDICES

Appendix I Questionnaire used for the socio-economic survey in selected homegardens of Thrissur district, Kerala

Municipality/Panchayat:

District:

Taluk:

Ward No. and Name:

Locality:

Name of the family leader :

Address :

Adults: Children: Total:

Primary occupation :

Annual income :

Extent of land owned :

Extent of Land (at present): ..... (in cents)

Land Fragmentation during the last two Decades (i.e., since 1990): YES /NO

If YES, Year of Fragmentation: .....

Causes of Fragmentation: .....

Extent of Land earlier to Fragmentation: ..... (in cents)

Other farm land areas (Specify type of land): .....

1. Main source of income : Agriculture/Business/Salary/others

2. Other Sources of Total Family Income (In Rupees per Annum)

	Present (2015)	Past (1990)
Remittances Received		
Income from salary/rent/business		
Income from Homestead Garden (selling products in the market)		
- Plantation Crops (e.g., Coconuts, Arecanut)		
- Spices		
- Fruit trees (e.g., Banana, Mango, Jackfruit)		
- Vegetables		
- Wood/Timber		
- Fuelwood		
- Grass/Fodder		
- Any Other		
Price of (income) homestead based consumables (List out various products)		
Income from Livestock		
Other Income		

3. Consumption expenditure (per month)

	Present (2015)	Past (1990) (in 1990 Rupees)
Total Expenditure		
Food Expenditure (other than homestead consumables)		
Household Consumption of homegardens products (in terms of market prices)		
Name the Various Products you get/used to get from the Homestead Garden for Household Consumption		
Medical Expenditure		
Expenditure for homestead maintenance (workout separately for each crop) - Cost of planting - Cost of fertilizers - Cost of labourers - Cost of irrigation - Cost of plant protection - Cost of harvesting and processing		

4. Source of energy for cooking: Cooking gas/ Electricity/ Kerosene/ Firewood

Monthly cost of cooking energy

Principle Source of Energy	Present (2015)		Past (1990)	
	Monthly Qty	Cost per annum	Monthly Qty	Cost per annum
LPG				
Kerosene				
Electric Heater				
Wood/Fuelwood/Biomass f Homestead Garden				
Other (Specify)				

4. Details on livestock

	Number	
	1990	2015
Cow		
Goat		
Pig		
Poultry		
Any Other		

5. Interest in planting new trees inside the homegarden: YES/ NO

If no why? :

6. CONSTRAINTS IN HOMESTEAD FARMING

Sl No	Constraints
1	Financial constraints
2	Market constraints
3	Technological constraints
4	Resource constraints
5	Social constraints
6	Psychological constraints
7	Institutional constraints
8	Others

PROFORMA FOR TREE ENUMERATION

Sl. No	Species	Height (m)		Girth (cm)	Volume m^3	Remarks
		Bole	Total			

DETAILS ABOUT AGRICULTRAL CROPS

Sl. No.	Crop	Number	Area

Appendix II List of all tree species identified from surveyed homegardens of Thrissur district with their functional groups

(Functional groups: 1- Timber, 2- Fruit tree, 3- Fodder, 4- Fuel, 5- Green manure, 6- Medicinal trees, 7- Ornamental trees, 8- Other use trees)

No.	Tree species	Functional group
1.	*Acacia auriculiformis*	1,4
2	*Acacia mangium*	1,3,4
3	*Adenanthera pavonina*	1,6
4	*Aegle marmelos*	3,4,6
5	*Ailanthus triphysa*	1
6	*Albizia chinensis*	1,4
7	*Albizia lebbeck*	1,3,4,5
8	*Albizia odoratissima*	1,3
9	*Albizia procera*	1
10	*Alstonia scholaris*	1
11	*Anacardium occidentale*	2,4
12	*Annona reticulata*	2,6
13	*Annona squamosa*	2,6
14	*Araucaria heterophylla*	7
15	*Artocarpus communis*	1,2
16	*Artocarpus heterophyllus*	1,2,3
17	*Artocarpus hirsutus*	1,2,3
18	*Averrhoa bilimbi*	2
19	*Averrhoa carambola*	2
20	*Azadirachta indica*	1,4,6
21	*Bauhinia malabarica*	7
22	*Bauhinia acuminata*	7
23	*Bauhinia purpurea*	7
24	*Bombax ceiba*	1
25	*Bridelia retusa*	1,4
26	*Butea monosperma*	1,4
27	*Caesalpinia coriaria*	7
28	*Caesalpinia sappan*	1,6
29	*Calophyllum inophyllum*	1
30	*Cananga odorata*	1,7
31	*Careya arborea*	1
32	*Carica papaya*	2
33	*Cassia fistula*	1,4,5,7
34	*Casuarina equisetifolia*	1,4
35	*Ceiba pentandra*	8
36	*Chrysophyllum cainito*	2
37	*Cinnamomum camphora*	6
38	*Cinnamomum malabatrum*	6
39	*Cinnamomum zeylanicum*	6
40	*Citrus maxima*	2
41	*Dalbergia latifolia*	1
42	*Delonix regia*	8
43	*Diospyros buxifolia*	1,7

44	*Erythrina indica*	1,3
45	*Ficus auriculata*	2,7
46	*Ficus callosa*	1
47	*Ficus exasperate*	1
48	*Ficus hispida*	8
49	*Ficus racemose*	2
50	*Ficus religiosa*	8
51	*Ficus tinctoria*	8
52	*Flacourtia inermis*	2
53	*Flacourtia montana*	2
54	*Garcinia gummi-gutta*	2
55	*Garcinia mangostana*	2
56	*Garuga pinnata*	3,4,5
57	*Gliricidia sepium*	1,3,4,5
58	*Gmelina arborea*	1,3,4
59	*Grewia tiliifolia*	1,3
60	*Hydnocarpus pentandra*	6
61	*Lagerstroemia flos-reginae*	7
62	*Lannea coromandelica*	1,3,4,5
63	*Laucaena leucocephala*	3,4
64	*Litchi chinensis*	2
65	*Macaranga peltata*	1,3,4
66	*Madhuca longifolia*	1
67	*Mallotus philippensis*	4
68	*Mangifera indica*	1,2,3,4,5
69	*Manilkara zapota*	2
70	*Michelia champaca*	1,7
71	*Mimusops elengi*	8
72	*Morinda pubescens*	8
73	*Moringa oleifera*	2
74	*Morus alba*	1,2,3
75	*Murraya koengii*	8
76	*Nephelium lappaceum*	2
77	*Peltophorum pterocarpum*	1
78	*Persea americana*	2
79	*Phyllanthus acidus*	2,6
80	*Phyllanthus emblica*	2,6
81	*Pimenta dioica*	2
82	*Plumeria rubra*	7
83	*Polyalthia longifolia*	7
84	*Pongamia pinnata*	1,3,4
85	*Pouteria campechiana*	2
86	*Psidium guajava*	2
87	*Pterocarpus marsupium*	1,3,5
88	*Samanea saman*	1,4,5
89	*Santalum album*	1,3
90	*Sapindus trifoliatus*	8
91	*Saraca asoca*	6
92	*Schefflera sps*	8
93	*Schleichera oleosa*	1,4

94	*Simarouba glauca*	6
95	*Spathodia campanulata*	7
96	*Spondias pinnata*	2
97	*Sterculia guttata*	2
98	*Strychnos nux-vomica*	1,6
99	*Swietenia macrophylla*	1
100	*Syzygium aqueum*	2
101	*Syzygium cumini*	1,2,3,4
102	*Syzygium jambos*	2
103	*Syzygium laetum*	2
104	*Syzygium malaccense*	2
105	*Syzygium samarangens*	2
106	*Tamarindus indica*	1,2,3,4
107	*Tecoma stans*	7
108	*Tectona grandis*	1,
109	*Terminalia bellirica*	1,4,6
110	*Terminalia catappa*	1,2,5
111	*Terminalia paniculata*	1,4
112	*Theobroma cacao*	2
113	*Trema orientalis*	4
114	*Vitex altisima*	1
115	*Vitex negundo*	1,6
116	*Wrightia tinctoria*	5,6
117	*Zanthoxylum rhetsa*	1
118	Unknown 1	8
119	Unknown 2	8
120	Unknown 3	8
121	Unknown 4	8
122	Koppakkaya(unknown 5)	8

Appendix III List of all agricultural crop species identified from surveyed homegardens of Thrissur district

Sl. No.	Agricultural crop species
1	*Abelmoschus esculentus*
2	*Adhatoda vasica*
3	*Amaranthus dubius*
4	*Amorphophallus paeoniifolius*
5	*Ananas comosus*
6	*Areca catechu*
7	*Asparagus officinalis*
8	*Benincasa hispida*
9	*Brassica oleracea* var. *botrytis*
10	*Brassica oleracea* var. *capitate*
11	*Capsicum annuum*
12	*Capsicum frutescences*
13	*Citrus limon*
14	*Coccinia grandis*
15	*Cocos nucifera*
16	*Colocasia esculenta*
17	*Cucumis melo* var. *conomon*
18	*Cucurbita moschata*
19	*Curcuma longa*
20	*Dioscorea esculenta*
21	*Hevea brasiliensis*
22	*Malpighia punicifolia*
23	*Manihot esculenta*
24	*Maranta arundinacea*
25	*Momordica charantia*
26	*Musa paradisiaca*
27	*Musa sps.* AAB (Palayankodan)
28	*Musa sps.* AAB (Nendran)
29	*Musa acuminata*
30	*Myristica fragrans*
31	*Ocimum sanctum*
32	*Phaseolus vulgaris*
33	*Piper nigrum*
34	*Plectranthus amboinicus*
35	*Solanum lycopersicum*
36	*Solanum melongena*
37	*Solenostemon rotundifolius*
38	*Trichosanthes cucumerina*
39	*Vanilla planifolia*
40	*Vigna unguiculata*
41	*Zingiber officinale*

DIVERSITY, STRUCTURE AND STANDING STOCK OF TIMBER IN THE HOMEGARDENS OF THRISSUR DISTRICT, KERALA

By

SUBU R UNNITHAN

(2014-17-109)

ABSTRACT OF THE THESIS

Submitted in partial fulfilment of the requirement for the degree of

MASTER OF SCIENCE IN FORESTRY

FACULTY OF FORESTRY

KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF SILVICULTURE AND AGROFORESTRY

COLLEGE OF FORESTRY

VELLANIKKARA, THRISSUR – 680 656

KERALA, INDIA

2017

162

ABSTRACT

Tropical homegardens are time-tested land use systems which have evolved through generations of crop intensification. Homegardens of Kerala are traditional agricultural systems that were closely related to the livelihood and nutritional security of small and marginal farmers of Kerala. A study was carried out to investigate the functional and structural status of the homegardens in Thrissur District, Kerala. Study was conducted in selected homegardens of 10 panchayths and one peri urban area of Thrissur district. The study was based on comparison of homegardens of three size classes such as small (<0.2 ha), medium (0.2-0.4 ha) and large (>0.4 ha) from three eco regions (highland, midland and coastal land) and one peri urban area (municipality). A total of 330 homesteads were selected from selected panchayths based on a stratified random sampling.

There was a great variability in diversity, abundance and standing stock of different tree species belongs to different use categories among three homegarden size classes and across different eco regions. There were 163 total species present in the entire Thrissur district that included 122 trees species and 41 agricultural crop species. Contrary to earlier studies, consistent decline in diversity was observed with decrease in homegarden size. Highest number of taxa was observed from large homegardens (102 species) which was followed by medium (95 species) and small (85 species). Population pressure and skewed land availability may have negatively affected the species diversity in homegardens. Most abundant functional group of trees found in surveyed homegardens were medicinal trees (62 species) followed by timber species (53 species). Economically important functional groups such as timber, fodder, fuel, green manure and other MPTs were abundant in large homesteads. Eco-region wise comparison of tree diversity suggested high diversity in the midland and highland regions while lower in coastal land and peri-urban areas. *Mangifera indica* was the predominant timber tree species in terms of abundance and standing stock in Thrissur district with a total stand number and standing stock projected to the Thrissur district as 15,98,849 and 18,84,356.3 m^3 respectively. Other dominant

timber trees in terms of standing stock were *Artocarpus heterophyllus, Tectona grandis, Swietenia macrophylla, etc.* Standing stock per hectare of total timber species identified in Thrissur district was 55.12 m^3 ha^{-1} and projected standing stock of all timber species in the district was 81,38,931.6 m^3. Vertical diversity of the studied homegardens suggested high species richness associated with middle storey. Also all three strata of large homegardens were more diverse than medium and small homegardens irrespective of eco-region. In total there were 41 species of agricultural crops and medicinal plants identified from selected homegardens. *Musa sps., Areca catechu and Cocos nucifera* were the predominant species of all size holds. Simpson Index and Shannon Diversity Indices of agricultural crops of all size holds showed no large difference.

Attempts to study the socio-economic factors of homegarden functioning revealed land fragmentation as the principal agent of their decline. The most frequent constraints of homegardens included high wage of the labourers involved in homegarden maintenance, less labour availability, large expense/less profit, pest and disease, etc. Wood quality assessment of *Tectona grandis, Artocarpus heterophyllus* and *Swietenia macrophylla* using NDT showed that oven dry specific gravity ($SPG_{o.d}$) has no influence on eco-regions and tree size classes. The dynamic modulus of elasticity (MOE_{dyn}) showed significant differences for *Artocarpus heterophyllus* and *Swietenia macrophylla* across eco-regions. However, this was not prominent for *Tectona grandis.* On the whole, the functional and structural analysis of the homegardens in Thrissur district of Kerala revealed their potential contribution to the agro-biodiversity. However concerted efforts are required to revitalize these unique traditional agricultural practices in terms of their ecological and economic viability.

174055

KERALA AGRICULTURAL UNIVERSITY CENTRAL LIBRARY