COMPOSITION, STRUCTURE AND DIVERSITY OF HOMEGARDENS AND IMPLICATIONS ON LIVELIHOODS IN MOSHI RURAL DISTRICT KILIMANJARO REGION, TANZANIA

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ABSTRACT

This study assessed the composition, structure and diversity of agroforestry homegardens and implications on the livelihoods of the local communities in Moshi Rural District in Kilimanjaro Region. Purposive sampling was used to select three villages which are Msuni, Rau and Chekereni Weruweru from highland, midland and lowland agro-ecological zones respectively. Primary data were collected using village surveys, on farm inventories, household interviews and focused group discussions. Data analyses was done using SPSS and excel softwares. The results revealed that there are five agroforestry systems practiced in the homegardens of the surveyed villages with Agrosilvopasture being the most widely practiced system followed by Agrosilvicultural, Agroaposilvipastoral, Agroaposilvicultural and Agroaquosilvopastoral. The technologies practiced in agroforestry homegardens are mixed intercropping, live fence and boundary planting. Agroforestry homegardens comprised of herbaceous crops, livestock, insects and fish under various interactions with woody perennials. There were 85 plant species comprised of 61 woody perennials and 24 herbaceous crops. The most dominant trees based on basal area are *Grevillea robusta, Albizia schimperiana, Persea americana* and *Manginifera indica.* A few additional crops have been introduced in the homegardens with increasing time including *Manihot esculenta, Vigna unguiculata* and *Cajanus cajan* due to their capacity to withstand drought. The production of different crops is said to have decreased in such a way that only 62.5% of the respondents currently meeting their annual household food requirements from their farms. A more diversified homegarden is needed so as to reduce dependence on the currently herbaceous crop and woody perennial based products only. Adoption of agroforestry technologies that can prevent soil erosion and capable of providing more nutritious rich leguminous leaves for ruminant animals are important. Alternative sources of household energy need to be sought to reduce dependency on fuelwood and promote the adoption of drought tolerant plants.

DECLARATION

I, DAFROZAH SAMAGWA, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

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LIST OF ABBREVIATIONS AND SYMBOLS

°C	Degree Celcius
CRBD	Complete Randomized Block Design
DBH	Diameter at Breast Height
E	Evenness
ENVIROCARE	Environmental, Human rights care and Gender Organisation
etc.	etcetera
FGD	Focus Group Discussions
ha	hecta
ICRAF	International Centre for Research in Agroforestry
Kg	Kilogram
m	metre
mm	milimetre
SPSS	Statistical Package for Social Science Studies
URT	United Republic of Tanzania

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Agriculture is the foundation of the Tanzanian economy that accounts for about half of the national income, three quarters of merchandise exports and is source of food and provides employment opportunities to about 80% of Tanzanians (URT, 2007). In most places it is rain fed agriculture hence depends on unreliable and irregular weather conditions that cause both crops and livestock to be adversely affected by periodical droughts. Since Tanzania's economy is largely dependent on agriculture, it is considered that sustainable development can be achieved when strategic actions, both short term and long term are put in place to address climate change impacts on agriculture and other key economic sectors (URT, 2007). The adoption of diversified land use systems such as agroforestry apart from agriculture, by the farming community can provide stability and sustainability to the farming systems. Agroforestry is a traditional land use system that is able to satisfy a large diversity of socio-economic needs in a sustainable way and in many different agro-ecological conditions (Depommier, 2003).

Agroforestry systems refer to practices in which crops, trees, animals and other components usage of land are combined either temporary or partially where the arrangement of different types of components and their level of interaction are distinct for individual agroforestry systems. Homegarden as one among many agroforestry practices is a garden around the homestead for the production of a variety of various products for both home consumption and income generation. It is the cultivation of land which may be at the back of the home or within a walking distance from home (Odebode, 2006). It has been a common agroforestry practice in many countries in the world. In Tanzania homegardens have also been practiced for a long time with the evidence of

the Chagga homegardens that are practiced in Kilimanjaro Region and the Haya homegardens in Kagera Region that have attracted many researches from different fields of studies (Rugalema, 1994b).

In this study, composition of homegarden refers to things made up the homegarden. Structure refers to arrangement of components in the homegarden. Diversity is the measure of the total number of species in the homegarden and their distribution pattern. This study covers structure and diversity of tree only and not other components. Composition and structure of different agroforestry homegardens vary from place to place and are influenced by ecological factors, such as climate, soil, and cultural factors. The diversity of agroforestry homegarden components corresponds to the different needs, constraints and strategies of rural societies, be they economic, social or religious, or even environmental (Depommier, 2003).

A homegarden is part of a household livelihood strategy and has gained prominence as a natural asset through which sustainable use of resources, particularly for the livelihoods of the poor, may be achieved. Livelihood refers to the capabilities, assets, activities and strategies required and pursued by households and individuals for a means of living (Carney, 1998). A livelihood is sustainable when it can cope with, and recover from, stresses and shocks and maintain or enhance its capabilities and assets both now and in the future, while not undermining the natural resource base (Chambers and Conway, 1991).

1.2 Problem Statement and Justification of the Study

The Chagga homegarden technology is an old traditional agroforestry practice that consists of a highland coffee-banana farm with multiple other food crops intercropped, and the lowland maize, millet and bean fields (Sioni, 2002a). Due to sub-division of land

between the sons of the family, homegardens have become increasingly fragmented such that most of them are too small to sustain families. This has resulted into changes in the composition, structure and possible decline in the productivity of the practice. It is possible that adoption of this technology at present may no longer contribute substantially to household's livelihoods. Several studies have documented the homegardens dynamics and status including the implications of population pressure and socio-economic changes on the farming systems and livelihoods of the people of the area, studies on changing landscapes on the southern slopes of mountain Kilimanjaro Tanzania (Soini 2002a, 2002b; Fernandes *et al.*, 1985; O'Kting'ati *et al.*, 1984). Based on these studies the possible changes in structure and composition of the homegardens and their implications on productivity and livelihood sustainability have not been well studied and documented. Therefore the study attempts to fill this gap of knowledge. The study is expected to contribute in the revival of homegardens for enhanced contribution to livelihoods in Kilimanjaro Region with wider implications in other similar areas in Tanzania.

1.3 Objectives of the Study

1.3.1 Main objective

The main objective of this study was to assess the composition, tree structure and tree diversity of homegardens and implications on the livelihoods of the local communities in Moshi Rural District Kilimanjaro Region.

1.3.2 Specific objectives

The specific objectives of this study were to:

i. Identify the agroforestry systems and technologies practiced in the homegardens.

ii. Assess the components composition, tree structure and tree diversity of the homegardens.

iii. Determine changes in composition of homegardens over time.

iv. Determine the implications of the changes to homegardens on related livelihoods

1.4 Research Questions

The study was guided by the following research questions:

i) What agroforestry systems and technologies are currently being practiced in agroforestry homegarden?

ii) What is the components composition, tree structure and tree diversity of the agroforestry homegardens?

iii) How have the agroforestry homegardens evolved over time in terms of composition, structure and species diversity?

iv) What are the implications of the changes in agroforestry homegarden composition on the livelihoods of the local communities?

CHAPTER TWO

2.0 LITERATURE REVIEW

Agroforestry is recommended for mountainous terrain in the tropics and subtropics, because it has always two functions: production (fuelwood, timber, fodder and other non-timber forest products) and services (increase in soil fertility and erosion control). The multifunctional nature of agroforestry can solve several problems simultaneously. Traditional practices have often become less diversified, unproductive and ecologically damaging. Improved agroforestry tries to take the best out of the traditional agroforestry methods and combine them with new scientific findings and inventions (Reyes, 2008).

2.1 Types of Agroforestry Systems and Technologies

Young (1989) reported that there are hundreds, possibly thousands of agroforestry systems but only 20 distinct practices are mostly practiced in different places. They are so complex and diverse that they need to be grouped and classified into different categories in order to evaluate them.

2.1.1 Criteria used in classifying agroforestry systems

Different writers have been classifying agroforestry systems based on different criteria. Nair (1993) used four bases for classification of agroforestry systems which are the structure of the system, the function of the system, the socio-economic scale and level of management and his last basis was ecological spread of the system. Dwivedi (1992) reorganized those bases into seven as follows; structure, physiognomic, function, floristic, socio-economic, history and ecological basis.

2.1.2 Different types of agroforestry systems

a) Agrisilviculture

This system combines the production of woody perennials (trees or shrubs, coconuts, bamboos etc.) with herbaceous crops, in space or time, to fulfill productive or protective roles within the land management systems. Agrosilvicultural systems can be classified into two main groups which are taungya whereby food crop production is allowed during the first few years of establishing timber plantations and long-term associations of timber trees whereby perennial crops or growing of food crops is allowed after routine thinning of the timber plantation. Mixing herbaceous crops and woody perennials can extend harvesting period hence ensuring the continuous availability of some food.

b) Agrosilvopasture

This system involves a three-way mixture based on a combination of herbaceous crops and woody perennials with animals and/ or pastures. It is also a common practice in some places that have sequential patterns (integration in time) of agrosilvicultural phase followed by a silvopastoral one. In Nepal, this system is classified as an agro-silvo-livestock keeping system which is further categorised into homegarden and tree-crop mix (Regmi, 2003). It is a system that requires skillful management, and can be sustainable even in harsh environments and fragile soils. This system can serve the tree, herbaceous crops and animal components at the same time through a partial indirect arrangement so that during the cropping season the animal can continue benefiting from the system through cut and carry mechanism of the fodder from the farm to the housed livestock.

c) Aposilviculture

This system integrates woody perennials and insects like bees, grasshoppers, locusts, butterfly and caterpillars. The insect component that has been integrated by many people

in their system is honey bees. This is because they require very little management and is very active and effective pollinators for many kinds of crops, the honey bees produce honey and a wide range of other products that are potential sources of income.

d) Agroaquosilviculture

This is a system that integrates woody perennials, herbaceous crops and aquatic life-forms (fish, shrimps, crocodiles, crabs, etc.). In this system various trees and shrubs preferred by fish are planted on the boundary and around fish ponds so that tree leaves can be used as feed for fish, to help stabilize the pond banks and protect pond from siltation. This is common in over 31 districts in Uganda where the common fishes are Nile tilapia, North Africa catfish, Carp, Tilapia zilli and others (Okia *et al.*, 2009).

2.1.3 Agroforestry systems in Tanzania

Tanzania is home to several traditional agroforestry systems and technologies that have been in practice for hundreds of years. Some have been documented such as the Chagga homegardens, the related Mara Region homegardens known as Obohochere and the traditional Wasukuma silvopastoral system called Ngitili (ICRAF, 2009 and Baijukya *et al.*, 2005). One outstanding aspect of these traditional methods is the use of multi-layered systems with a mixture of annual and perennial plants, which imitate natural ecosystems. Trees form an important component of agroforestry systems. Through careful tree selection, farmers have deliberately shaped tree production on their farmland to fulfill their specific needs; traditional medicines as well as basic food commodities, including a variety of gums, oils, proteins, fruits and drinks, which are of nutritional importance for a large number of people, especially in rural areas (Bationo *et.al.*, 2008).

2.1.4 Agroforestry Technologies

Agroforestry technologies are sub-systems of agroforestry systems that are characterized by the way the components in the agroforestry system are structured or arranged on the resources management unit. Nair (1993) defined an agroforestry technology as an innovation or improvement usually through scientific intervention to either modify an existing system or practice or develop a new one.

2.1.4.1 Criteria used in classifying agroforestry technologies

Agroforestry technologies can be classified as traditional practices that evolved through the experience accumulated by generations of farmers, examples of technologies are homegardens, live fences, shelterbelts, hedgerow barriers, alley farming and improved fallows (Young, 1989). Past studies have shown that agroforestry systems and technologies can also be prioritised and/or classified according to ecological zones and/or problem domain areas in order to provide a framework for evaluating those systems, technologies or practices and to develop action plans for their improvement (Okia *et al.*, 2009).

2.1.4.2 Agroforestry technologies in practice

a) Homegardens

Homegardens have been defined differently by many authors but Fernandes and Nair (1986) defined them as the land-use practices involving deliberate management of multipurpose trees and shrubs in intimate association with annual and perennial agricultural crops and invariably livestocks within the compounds of individual houses, the whole crop-tree-animal unit being intensively managed by family labour. The combination of trees, shrubs, vines, botanical pesticides, plants of medicinal and religious value and herbaceous plants yield firewood, small poles and posts, forage and

fodder, vegetable crops, green manure, fruits and nuts, and flowers in varying combinations for the home or sale (Ffolliott, 2005). Similarly, poultry, fishes, honeybees and cattle or goats or pigs are raised to meet family requirements throughout the year (Pulami and Paudel, 2006).

b) Live fences

This is a technology in which a line or several lines of woody perennials are planted around a land management unit of either herbaceous crops or livestock to keep farm animals in an enclosed area (e.g. a pen where cattle pass the night) or to keep them out of a cropped area (e.g. a homegarden). Apart from being used to control movement of animals they can also control movement of people, provide fuelwood, fodder, food, act as windbreaks and enrich the soil depending on the species used (Okia *et al.*, 2009).

c) Alley farming

Alley farming is a technology in which strips (or alleys) of annual crops are grown between rows of trees or shrubs (Ffolliot, 2005). The main purpose of this method is to maintain or increase crop yields by improving the soil and micro-climate through the cycling of nutrients, mulching and weed control. When well structured and managed, alley farming can also act as soil control mechanism.

d) Boundary planting

This technology involves lines of trees or shrubs planted along farm boundaries or on the borders of farmyards, pasture plots, animal enclosures or around agricultural fields. Living fences serve mainly as field boundaries. They can be made of single or multiple, densely planted rows consisting of a mixture of plant species.

e) Mixed intercropping

This is a technology in which woody perennials and herbaceous crops are intimately associated in various forms of woody perennials arrangement and spacing in order to maximize beneficial interaction while minimizing competition. Mixed intercropping can also increase biodiversity, stability and product diversification of the farm (Kantor, 1999). Various types of arrangements are square arrangements, irregularly scattered trees or shrubs on the landscape and the rarely used systematic arrangement.

2.2 Compositions, Tree Structure and Diversity of Agroforestry Homegardens

2.2.1 Compositions of agroforestry homegardens

The main components of agroforestry systems are trees and shrubs, herbaceous crops, livestock, insects and aquatic life forms. Homegarden is one among many agroforestry technologies which has been practiced in different places (ICRAF, 2009). It contains different components that are chosen basing on the dietary habit of the society, market demands of the locality, environmental and social economic factors. In Tanzania, studies conducted in West Usambaras', Kagera Region, Arumeru, Kibaha, Rombo and Ukerewe Districts' homegardens recorded the integration of agricultural crops, trees/shrubs and animals (Baijukya *et al.*, 1992; Kaihura *et al.*, 2001; Makawia, 2004; Moshi, 1997; Rweyemamu, 2001; Shalli, 2003; Shayo, 2005). In West Java, particularly in the Priangan Region, fish ponds often form part of the homegardens.

The Chagga agroforestry homegardens have been integrating coffee, bananas, beans, cow peas, maize, onions, potatoes, taro, sweet potatoes, tomatoes, yams, egg plants, sweet pepper, cattle and timber trees on the open fields on the lower slopes of mountain Kilimanjaro and plains (Fernandes *et al.*, 1984 and Soini, 2002a). In sub-humid Arumeru

main components in homegardens are coffee, banana, maize, beans, different trees and stall fed animals (Kaihura *et al.*, 2001).

2.2.2 Tree structures of agroforestry homegardens

2.2.2.1 Arrangement of components in agroforestry homegardens

Agroforestry homegardens can be arranged in various ways depending on the preference of the owner. Examples are horizontal arrangement, vertical arrangement and size arrangement.

a) Vertical arrangement of agroforestry homegardens

Vertical structures of homegardens reflect their degree of specialization and complexity that are caused by a mixture of annuals and perennial plants of different heights. In general homegardens consist of an herbaceous layer near the ground, a tree layer at the upper level that consists of emergent, fully grown timber and fruit trees, and intermediate layers dominated by various fruit trees in between. The lower layer is dominated by different vegetables, medium plants and food crops, the combinations of crops are largely dictated by the length of the growing season, the fertility and water-holding capabilities of the soil, whether the crops are rainfed or irrigated, and the personal preference of the gardener (Nair, 1993; Ffolliott, 2005). The study conducted in Southwestern United States and Northwestern Mexico documented that homegardens in those regions are arranged in such a way that tree layers are at the upper levels of the gardens, herbaceous layers located near, on, or in the ground, and intermediate shrub or vine layers (Ffolliott, 2005). Many studies reveal that homegardens are multi-storied, commonly containing three to five layers (Albuquerque *et al.*, 2005; Bamidele *et al.*, 2011; Das and Das, 2005). In Tanzania, the Chagga homegardens' structural arrangement of plants mainly consists of the shade trees, coffee (*Coffea arabica*) and bananas grown for food and sale. In order

to meet their shade requirements, the agricultural crops are intimately intermixed in a complex arrangement with a higher canopy of indigenous or planted multipurpose trees. There is also a middle canopy of fruit and multipurpose trees/shrubs; followed by a lower ground cover of food crops, medicinal plants and annual fodder plants (Ok'tingati and Kessy, 1991; Kitalyi *et al.*, 2013).

b) Horizontal arrangement of agroforestry homegardens

In most homegardens horizontal arrangement of components is haphazard with no specific niche for specific crop (Kebebew *et al.*, 2011). The high diversity of plants in homegardens forms a complex horizontal structure that can be described by density or basal area of components. The wide spacing of trees in farms results into low density of trees and vice versa, this was recorded by Kumar (2011) in Central Kerala whereby there were more trees on small gardens on a unit area (71 trees ha^{-1}) and in medium and large unit areas 26 and 16 trees ha^{-1} respectively. The density of trees in homegardens varies widely among and within sites. For instance different studies that have been conducted in India show the estimated plant density of 1535 ha^{-1} and basal cover of 33.86 m^2 ha^{-1} in the North East homegardens, tree and palm densities of 750 to 4600 individuals ha^{-1} have been recorded in Kerala and tree density of 831 trees ha^{-1} and total basal area of 9.54 m^2 ha^{-1} (Das and Das, 2005; Chandrashekara and Baiju, 2010; Devi and Das, 2012). In Tanzania, the west Usambara's homegardens have the tree densities with a range of 17-40 trees ha^{-1} (Moshi, 1997). Factors that can affect the density and richness of trees are ecological conditions such as rainfall and temperature, socioeconomic factors such as marketing and the level of household resources such as land holding (Abebe, 2005).

2.2.3 Diversity of homegardens

Species diversity is a measure of the variety of different animals and plant species in their respective community. There are two components of species diversity that can be measured which are the total number of species in a community (species richness) and the distribution pattern of individuals between the species.

One of the typical features of tropical homegardens is the high diversity of their components that give the agroforestry homegardens their biological stability and provides for a variety of family needs while making maximum use of the limited space available. Different studies that have been conducted documented that there were about 56 species of plants in a single homegarden of west Java Indonesia, 131 species in Nepal, more than 120 species in India, 36 species in Nigeria, 69 species in Nhema Zimbabwe (Abebe, 2005; Pandey, 2008; Depommier 2003; Olajide-Taiwo *et al.*, 2010; Maroyi, 2009). There are studies that document numbers of species and their uses. For example, in Sri Lanka a total of 289 species were observed, including 105 food plant species, 34 medicinal plant species and 148 ornamental species; in West Java homegardens 47 of species were ornamental, 22 fruits, 18 vegetables, 12 building materials and fuel wood (Christanty *et al.*, 1986; Kumari *et al.*, 2009).

Molebatsi *et al.* (2010) studied the number of plant species per homegarden and recorded 39±18 species in deep rural areas, 35±16 per garden for rural areas and 25±10 per garden for peri-urban areas. The above studies show that it is not only the richness that matters but also the heterogeneity in functions as most of homegardens involve appropriate mixtures of different functional groups of crops to meet balanced nutrition and cash needs of households.

Homegardens in Zimbabwe are very diverse in usage of plant species as Maroyi (2009) reported the uses of plants are vegetables, timber, firewood, construction material, fruit trees, ornamentals, hedging and shade plants, medicinal plants, cereals, tubers, oil crops, and others with miscellaneous uses. The Chagga homegardens were found also to be a very diverse farming practices. According to O'Kting'ati *et al.* (1984) there are 111 plant species including 53 tree species, 29 food crop species, 21 economically useful non-woody plant species and 8 weed species on thirty farms in six villages in Hai District on the southern slopes of Kilimanjaro.

In spite of the diversity of trees in most tropical homegardens to be generally high, many reports on homegardens do not single out the trees instead they indicate the total number of plant species present in the systems. However, there are some reports that indicated the number of woody perennials present in the homegardens (Fernandes *et al.*, 1984; Abebe, 2005). Studies conducted in Indonesia found that by comparing lowlands and highlands homegardens, homegardens in highland areas have lower plant diversity and simpler species composition (Wiersum, 2006).

2.2.3 Dominance of trees

a) Dominance by basal area

Basal area provides a better measure of the relative importance of the species than simple stem count. Therefore, species with the largest contribution in basal area can be considered as the most important woody species in the forest (Disssanayake and Hettiarachchi, 2013).

b) Dominance by family

A study conducted in Meru, mount Kenya Agroforestry ecosystem in Kenya found a total of 64 plant families with major families being Rubiaceae (with 22 species), Euphorbiaceae (21) and the subfamily Papilionoideae (19), the remaining 18 families were represented by a single species only (Lengkeek *et al.*, 2005). Study done across the homegarden in Sri Lanka observed 93 plant families with the most common families being Fabaceae, Araceae, Euphorbiaceae, Apocynaceae, Solanaceae, Rutaceae, Orchidaceae, and Cucurbitaceae (Kumari and Kansuntisukmongkol, 2009). In the study by Molebatsi *et al.*, (2010) in South Africa recorded the five largest families from the homegardens namely Asteraceae (85 species), Poaceae (54 species), Fabaceae (52 species), Solanaceae (26 species) and Lamiaceae (22 species).

2.3 Changes in Agroforestry Homegardens

Homegardens undergo a constant developmental process that involves gradual changes in the land use, composition and use of products according to the circumstances and needs of the farmers. The homegardens structures and compositions change with time whenever socioeconomic factors change. In Nepal, traditional types of homegardens have been transformed over time either to specialize and or commercialize and with fewer plants and animal species due to ever rising population, introduction of new technologies and plant and animal species (Pulami and Paudel, 2006). In Ethiopia, agroforestry homegardens were found to undergo land use changes since the 1990s as a result of increasing market economy, production and trading of cash crops that have led to reduced areas proportions of major staple foods, vegetables, root tubers, pulse, coffee, livestock and trees (Gebrehiwot, 2013). This leads to disappearance of many important and useful plant species.

According to Soini (2002a) by the year 1961 a few plants made, mainly of sweet potatoes, vegetables, trees were being grown alongside small patches of grazing lands. By the year 2000, more food was needed to be produced causing more land to be taken from the agroforestry homegardens on the upper slopes leading to reduction in the number of trees and concentration on vegetable gardens on immediate surroundings. In Bukoba, the study conducted by Baijukya *et al.* (2004) found out that in the years 1961 to 1999 the cropping patterns of agroforestry homegardens had changed from a predominance of bananas, coffee and beans to a more complex mixed cropping of bananas, coffee, beans, maize and various root crops. The major causes of changes were increasing population density, poor crop market and poor banana production whereby by 1999, banana production had declined by 20% leading to planting of more roots/tuber crops.

2.4 Agroforestry Homegardens Productivity in Relation to Livelihoods

Livelihood refers to the capabilities, assets, activities and strategies required and pursued by households and individuals for a means of living. After doing livelihood analysis the results are livelihood assets that define the context which influences, and to a large degree, defines the options available to, and constraints on, households in pursuit of their livelihoods (DFID, 2000). There are five types of livelihood assets that are namely human, natural, social, physical and financial capitals but in the context of this study the focus will be on natural capital. Natural capital refers to the natural resource stock from which resource flows and services important to livelihoods are derived. There is a wide variation in the resources that make up natural capital, from intangible public goods such as the atmosphere and biodiversity to divisible assets used directly for production (DFID, 2000).

Since homegardens involve the intimate mix of diversified agricultural crops, multipurpose trees and other components such as animals, insects and aquatic life forms, they have been producing sustained yield in a most resource-efficient way (Nair, 1993; Abebe *et al.*, 2010). Due to integration of different agriculture components in homegardens, the productivity of each component increases stability in income. Although homegardens cover a small portion of the land, their output is very important for sustaining livelihoods of the households as they ensure sustainable food security by increasing availability, accessibility, and utilization of food products, produce supplementary staple crops and also serve as sources of income for several families by selling the surplus cereals and vegetable, livestock, poultry, fish, honey in local market (Galhena *et al.*, 2013; Maroyi, 2009; Pulami and Paudel, 2006; Regmi, 2003). In Bukoba, a homegarden of one hectare was capable of producing 175 bunches of bananas per annum, 135 kg of coffee per year, 200 kg of beans per year, and 1250 litres of milk per year (Rugalema et al., 1994b). In Moshi, an average agroforestry homegarden of 0.68 ha produces about 125 kg of beans, 280kg of parchment coffee and 275 bunches of bananas (Fernandes *et al.*, 1985).

A homegarden has been described as an important social and economic unit of rural households, from which a diverse and stable supply of economic products and benefits are derived. For example Krishnal *et al.* (2012) recorded, 10.18% of the income of households in Batticaloa District was contributed by homegarden trees and more than 45% of the household income was contributed by homegardening in surveyed area. When comparing dependence on homegarden and off-farm activities as a source of income Meena and O'Keefe (2007) discovered that respondents in Rombo district relied significantly on farm production for income generation as coffee accounts for fifteen per cent of the average households income, compared with three per cent in Moshi Rural

District, bananas make up twenty eight per cent of income in the average Rombo household with only eight per cent in Moshi Rural, fifty per cent of household income in Moshi Rural is from off-farm sources, but only twenty seven per cent is in Rombo.

The productivity of agroforestry including homegardens in particular has been reported to decline with time partly due to inadequate return of nutrients to compensate for losses occurring through crop harvests and cause gradual decline in soil fertility, acerbated by decrease in cattle population, fragmentation of agroforestry homegardens due to human population growth, increasing pressure of crop pests and diseases and lack of enough cash to manage the gardens (Rugalema *et al.*, 1994a). The main impacts of decreased productivity and profitability of Chagga homegarden is reflected in the livelihood of the Kilimanjaro region inhabitants to the extent that income per capita in the region is currently one of the lowest in Tanzania (Kitalyi *et al.*, 2013).

Increased agroforestry homegardens production and productivity are however more needed now for improving human nutrition, particularly in poor traditional households in developing countries.

CHAPTER THREE

3.0 MATERIAL AND METHODS

3.1 Materials

3.1.1 Location of the study area

Moshi Rural District is among the six districts of Kilimanjaro Region, other districts are Moshi Urban, Mwanga, Same, Rombo and Hai. Kilimanjaro Region is located on the north eastern part of Tanzania mainland. It borders Kenya to the North, Tanga Region to the East and Arusha Region to the West.

The Chagga homegardens are found along the slopes on Mt. Kilimanjaro in northern Tanzania. The bulk of the mountain covers about 3000 km^2 and the highest peak is 5895m above sea level. It lies between latitudes 3°00′ - 3° 20′ South of equator and longitudes 37°00′- 37°40′ East of Greenwich. The area above the 1900m contour is a designated forest reserve and national park. The homegardens are located mainly between 900 and 1900m above sea level and cover about 1200 km^2 (120 000 ha) on the southern and eastern slopes of Mt. Kilimanjaro. The study was conducted in Moshi Rural District that lies between longitude 37° to 38° East and latitude 2° 30′ - 50° South of the Equator. On the North it borders Rombo District, on the East it borders Kenya on the South borders Mwanga and Simanjiro Districts and to the Western side it borders Hai District. The district has 31 wards that are comprised of 145 villages (Kilimanjaro Region Socio Economic Profile, 2002).

3.1.2 Description of the study area

3.1.2.1 Climate

(a) Rainfall pattern

Rainfall pattern is highly dependent on altitude. The district in some years enjoy two rain seasons one being between October to December while the normal rain season is from March to June. The Lowlands receive an average of 600 mm, the midland 1100 mm and the Highlands 1600 mm.

(b) Temperature

The district has an average daily temperature of 26° C. The highest temperatures occur in the months of February, March, April, September, October and November during which the mean maximum temperatures are around 31° while the mean minimum temperatures are in June, July, December and January when the temperatures go down to about 15°C.

3.1.2.2 Population size, growth and density

The district population according to 2012 census is 466 737 out of this 225 767 are males and 240 970 are females. The population is growing at the rate of 1.8 per year. The population density is 124 people per square kilometer (URT, 2013).

3.1.2.3 Agro-ecological zones

The district has 3 agro ecological zones as indicated in Table 1.

Table 1: Categorization of agro-ecological zones basing on altitudes in Moshi Rural District

Zone	Altitude meters	Rainfall mm	Major crops grown in the area
Lower Zone(Lowland)	700 - 900	400 - 800	Paddy, maize, sugar cane by irrigation
Middle/Central Zone	901 – 1500	900 – 1400	Maize, bananas, beans, diary cattle
Upper Zone (Highland)	1501 – 5895	1401 – 2000	Coffee, bananas, maize, avocados, beans, natural forest.

Source: Moshi District Council (2008)

3.2 Methods

3.2.1 Sampling procedure

The sampling procedure used in this study was purposive sampling and simple random sampling. Three villages which are Msuni, Rau and Chekereni Weruweru were chosen purposively from all villages by considering the elevation. The area was stratified by elevation into highlands (above 1500 m above sea level.); midlands (900 – 1500 m.) and lowlands (below 900 m). Sample villages were allocated to the strata based on area. Simple random sampling was used in selecting 120 households for studying that were divided into 40 households per village.

3.2.2 Data collection and analysis

3.2.2.1 To identify the agroforestry systems and technologies of agroforestry homegardens practiced

This was conducted by using village surveys to determine the interacting components of the agroforestry practices. Village surveys included formal and informal surveys guided by structured questionnaire and checklists of probe questions in selected villages. Information collected were types and conditions of agroforestry systems and technologies of agroforestry homegardens in place. Data was analyzed by SPSS using the CRBD statistical model and summarized into tables and graphs showing the types of agroforestry systems and technologies of agroforestry homegardens practiced in each ecological elevation zone.

3.2.2.2 To assess the composition, structure and diversity of homegardens

Assessment of composition, structure and diversity of different technologies was conducted through on farm inventories. At each agro-ecological zone the selected households were considered as inventory plots. In each plot all plants encountered were

identified and documented in the field using both local and botanic names (both herbaceous crops, trees and other components). For trees, each tree encountered was measured for diameter at breast height (DBH). The data was analysed into species composition essentially a list of all plant species encountered, Species richness was obtained by aggregating numbers of species across all agroforestry systems for that situation. Dominance of particular species was assessed on the basis of their frequency of occurrence over all farms in each situation.

Homegardens structure was determined based on the proportion of each plant encountered; density of tree species that were obtained by counting the total numbers of individual tree/shrub species present in the farmland of each farmer and basal areas of trees. Species diversity was computed using Simpson and Shannon Wiener indices (Shannon and Weaver, 1949) of diversity. An additional measure of evenness (E), which compares the observed distribution with the maximum possible even distribution of the number of species in the sample (Pielou, 1969) was calculated. The measure of evenness (E) is the ratio of observed diversity to maximum diversity (Magurran, 1988).

The following formulae were used to compute species diversity

Shannon Wiener Index:

$H = -\sum(Pi ln Pi)$ OR $-\sum Pi^2$ ..... (1)

Whereby H represents Shannon Wiener Index, Pi represents proportion of individuals of species i in the community (= ni /N; where n is the number of individuals of a given species and N is the total number of individuals in a sample)

Simpsons Index:

$D = 1-\{(\sum n(n-1))/(N(N-1))\}$ ..... (2)

Where D represents Simpson's index, n represents the total number of organisms of a particular species and N the total number of organisms of all species.

Evenness:

E = H'/Hmax, = H' /ln S.....(3)

Where E represents evenness and H' represents the Shanon index

3.2.2.3 To determine changes in composition over time

Data was collected through literature review, household interviews and focus group discussions (FGD). The village government officials formed the focus groups. The household interviews and focus group discussions included formal and informal discussions guided by the structured questionnaire and checklist of probe questions that availed the desired information. In household interviews the information collected included types of crops that used to be grown in different years in the past, current crops grown on farms (partly obtained from on farm inventories), reasons for adoption of each agroforestry component and causes of such changes. The information was summarized into past and current components grown and reasons for their adoption.

3.2.2.4 To determine the implications of the changes to agroforestry homegardens on the livelihoods of the local communities

Structured questionnaire, formal and informal interviews and field observation were used to collect data on production levels (yield) of the different agroforestry components and socio-economic information for each household surveyed. The data was analysed using the SPSS tool.

CHAPTER FOUR

4.0 RESULTS

4.1 The Agroforestry Systems and Technologies Practiced in the Homegardens of the Local Communities in Moshi Rural District

4.1.1 The agroforestry systems

The results show that there are five agroforestry systems practiced in the surveyed villages of Moshi Rural District. In general, Agrosilvopasture is the most widely practiced system followed by the Agrosilvicultural, Agroaposilvipastoral, Agroaposilvicultural and Agroaquosilvopastoral systems in that descending order of wide use (Table 2). The agroforestry systems practiced in the various agro-ecological zones is presented in Fig. 1.

Table 2: Agroforestry systems practiced in agroforestry homegardens of Moshi Rural District

Agroforestry system	Frequency	Percent
Agrosilvopasture	84	70.0
Agrosilvicultural	18	15.0
Agroaposilvipastural	16	13.3
Agroaquosilvopastoral	1	0.8
Agroaposilvicultural	1	0.8
Total	120	100.0

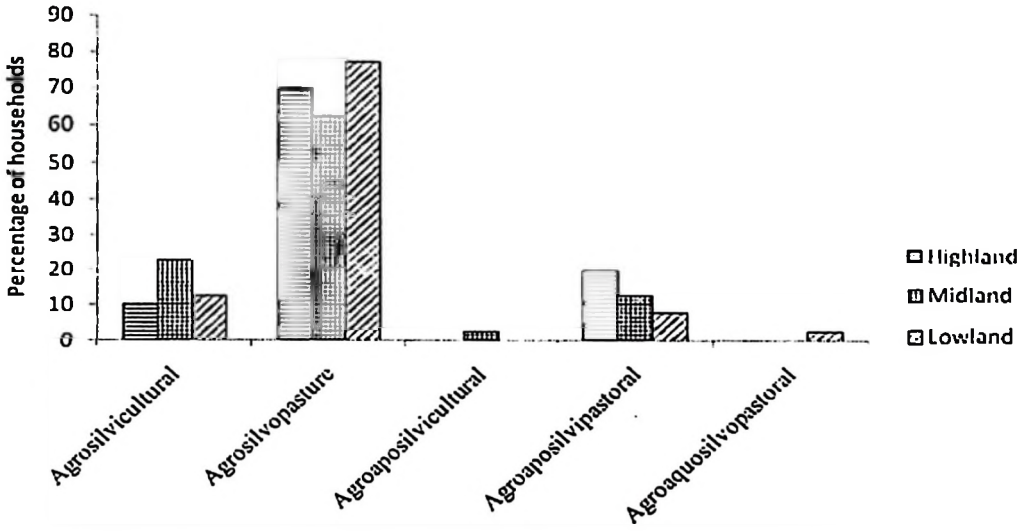

Figure 1: Types of agroforestry systems practiced in the various agro-ecological zones of Moshi Rural District

4.1.2 Agroforestry technologies practiced in the homegardens of Moshi Rural District

Agroforestry technologies practiced in the sampled households were Mixed intercropping, Live fence and Boundary planting. Most of the homegardens had all the three technologies in their farms.

4.2 The composition, Structure and Diversity of the Agroforestry Homegardens

4.2.1 The composition of agroforestry homegardens

Agroforestry homegardens in Moshi Rural District were found to comprise of various components under various interactions. A total of 86 plant species was recorded in all agro-ecological zones (Appendix 1). Woody perennials and herbaceous crops were present in all homegardens in all agro-ecological zones followed by livestock and insects that were found in some homegardens while a fish pond was observed in one household in the lowland agro-ecological zone only.

4.2.1.1 Woody perennials

A total of 61 species of woody perennials and shrubs were recorded in all agro-ecological zones. Trees that are found in the studied areas were 25 species in highland, 45 species in midland and 44 species in lowland agro-ecological zones. Trees are mainly used for fuel wood, timber, medicines, live fences, ornaments, windbreak, shading, fodder, boundary marking, poles production and source of edible fruits. Fruit trees comprised of 28.9% of all trees, timber 30.1%, fodder 6%, ornaments 6%, other roles such as windbreaking, shading and fuelwood are provided by all the trees found in the garden. By frequency of occurrence, the most dominant tree species in the highlands were *Grevillea robusta*, *Persea americana*, *Albizia schimperiana*, *'Mugoni'* and *Rauwolfia caffra* while the least common tree species were *Citrus limon*, *Citrus tangerine*, *Citrus sinensis*, *Dalbergia melanoxylon* and *Terminalia superba* (Appendix 2).

In midlands the most dominant tree species were *Grevillea robusta*, *Persea americana*, *Manginifera indica*, *Cedrela odorata* and *Cordia abyssinica* while the least common tree species were *Malus sieversii*, *Eriobotrya japonica*, *Prunus persica*, *Newtonia buchannanii*, *Jatropha curcas* and *Pouteria campechiana* (Appendix 3). In lowlands, the most dominant tree species were *Grevillea robusta*, *Mangifera indica*, *Senna siamea*, *Carica papaya*, *Persea americana*, and *Citrus limon* while the least common were *Pouteria campechiana*, *Maragaritarid discoidea*, *Senna singueana*, *Anacardium occidentale* and *Jacaranda acutifolio* (Appendix 4).

4.2.1.2 Herbaceous crops

A total of 24 species of cultivated herbaceous crops was recorded in the study site (Table 4). Among these, 2 species (maize and beans) were the most dominant in all agro-ecological zones. Along agro-ecological zones, the number of homegardens with coffee

and bananas decreased from the highland to lowland agro-ecological zones. More results on herbaceous crops in different zones are presented in Fig. 2.

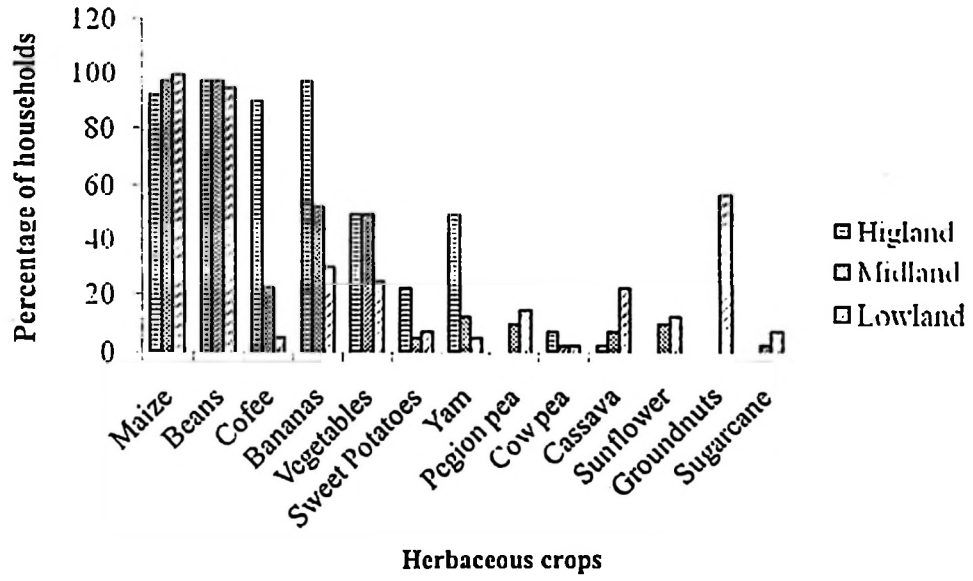

Figure 2: Herbaceous crops in agroforestry homegardens of different agro-ecological zones in Moshi Rural District

Table 3: Fruit plants commonly found in agroforestry homegardens of Moshi Rural District

Botanical Name	Common Name	Venacular Name
Artocarpus heterophyllus	Jack fruit	Mfenesi
Anacardium occidentale	cashew	Mkorosho
Mangifera indica	Mango	Mwembe
Sorindeia madagascariensis		Mgweda
Tamarindas indica	Tamarind	Mkwaju
Punica granatum	Pomegranate	Mkomamanga
Terminalia catappa	Tropical almond	Mkungu
Adansonia digitata	Baobab	Mbuyu
Psidium guajava	Guava	Mpera
Syzygium cumini	Jambul	Mzambarau
Annona muricata	Soursop fruit	Topetope
Eriobotrya japonica	loquat	Mstafeli
Malus sieversii	Wild apple	Apple pori
Prunus persica	Peach	Sesu
Citrus limon	Lemon	Mlimau, ndimu
Citrus sinensis	Sweet orange	Mchungwa
Citrus tangerina	Tangerine	Mchenza
Pouteria campechiana	Canistel	Mzaituni

Table 4: Herbaceous crops recorded in various agroforestry homegardens in Moshi Rural District

Botanical Name	Common Name	Venacular Name
Colocasia esculenta	Taro	Maduma
Helianthus annuus	Sunflower	Alizeti
Ipomea batatas	Sweet potatoes	Shisowia
Dioscorea elata	Yam	Ngao, shia
Dioscorea bulbifera	Yam	Nduu
Manihot esculenta	Cassava	Muhogo
Arachis hypogaea	Peanut	Karanga
Cajanus cajan	Pigeon pea	Mbaazi
Saccharum officinarum	Sugar cane	Miwa
Zea mays	maize	Mahindi
Phaseolus vulgaris	Beans	Maharagwe
Vigna unguiculata	Cowpea	Kunde
Musa nana	Banana/ plantain	Kinguruwe
Musa paradisiae		Mshare
Amaranthus spp.		Mchicha
Cucurbita maxima	Pumpikins	Maboga
Vigna unguiculata	Cowpea	Mkunde
Allium cepa	Onion	Kitunguu
Capsicum annum	Red pepper	Pilipili
Capsicum frutescene	Bird chillies	Ngogwe
Lycopersicon esculentum	Tomato	Nyanya
Solanum nigrum		Nafu
Brassica carinata	Figiri	Loshuu
Carica papaya	Pawpaw	Mpapai

4.2.1.3 The various animals kept in agroforestry homegardens of Moshi rural district

Apart from farming the households surveyed are also engaged in livestock keeping. Animals that are in the homegardens are cattle, goats, chicken, sheep, pigs and ducks. In many homegardens the cattle, goats, pigs and sheep are zero grazed. Animals are not allowed to go out without any guidance to prevent them from destroying crops on farm. Some farmers allow chicken and ducks to scavenge for food around the households when there are no crops that they can destroy. Livestock keeping in the district was dominated by chicken followed by goats then cattle, pig, sheep and ducks being the least (Appendix 6). A large number of households in the highlands keep cattle and chicken compared to other zones while in the lowlands there are more households keeping goats, sheep and pigs compared to other zones (Fig. 3).

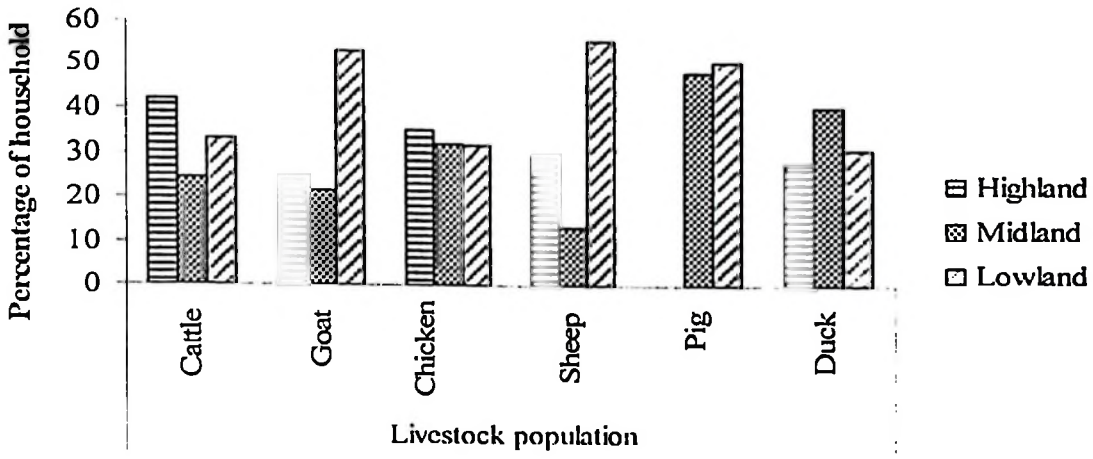

Figure 3: Percentage of households keeping various animals in Agroforestry homegardens of the Moshi Rural District

4.2.1.4 The insect component

Another component that forms part of the agroforestry systems of the homegardens in the study area was the insects, mainly honey bees. Some of the households had beehives that are used for practicing traditional beekeeping.

Table 5: Households engaged in beekeeping in all agro-ecological zones of Moshi Rural District (n=40)

Agro-ecological zone	Total number of households	Number of beehives	Average number of beehives	Percentage of households
Highland	6	20	3.3	15
Midland	4	12	3	10
Lowland	3	5	1.5	7.5

4.2.1.5 Aquatic component of the Agroforestry homegardens in Moshi Rural District

Aquatic life forms component is among the potential components in the Chagga homegardens due to the availability of flowing water especially in the highland agro-ecological zone but during this study there was only one fish pond recorded in the lowland agro-ecological zone and none in the others (Table 6). The pond was constructed by the ENVIROCARE project that is operating in the district.

Table 6: Households engaged in fish keeping in agroforestry homegardens of Moshi Rural District (n=40)

Village	Total number of households	Number of fishponds	Percentage of households
Highland	-		
Midland	-		
Lowland	1	1	2.5

4.2.2 Tree structure of homegardens

4.2.2.1 Vertical structure

Spatial arrangement of homegardens was irregular and random. The vertical arrangement of different storeys was obvious and clearly recognized. The lowest stratum of 0 - 1 m consisted of different herbaceous crops which include beans (*Phaseolus vulgaris*), cowpeas (*Vigna unguiculata)* and various vegetables. The second stratum which ranged from 1- 3 m high consisted of cassava (*Manihot esculenta*), pigeon peas (*Cajanus cajan*), maize (*Zea mays*), coffee (*Coffea arabica*), sugarcane (*Saccharum officinarum*). The third stratum ranged from 3 – 5 m high consisted of *Citrus spp,* mango (short variety), *Carica papaya* (pawpaw), *Jatropha curcas*, *Musa spp* (bananas), *Psidium guajava* (guava). The fourth stratum ranged from 5 - 30 m high was occupied by the various timber, fodder, fruit and shade tree species such as *Rauvolvia cafra, Cordia africana, Grevilliea robusta.* A considerable overlapping of the strata with continuous recruitment to the various zones was observed.

4.2.2.2 Horizontal structure

4.2.2.2.1 Density of trees

Since homegardens comprise of many species with different requirements it was difficult to estimate the species densities of all plants except tree species. The total number of trees recorded in the survey was used to calculate the species density in the homegardens. Areas of homegardens range from 0.2 to 1.6 ha in the highlands agro ecological zone, 0.1

to 1 ha in the midland and 0.1 to 1.2 ha in the lowland zone. The average density of trees in the agroforestry homegardens was 78 stems ha^{-1} with the highest mean tree density recorded in the midlands followed by the lowland zone and the highland agro-ecological zone had the lowest tree density (Fig. 4).

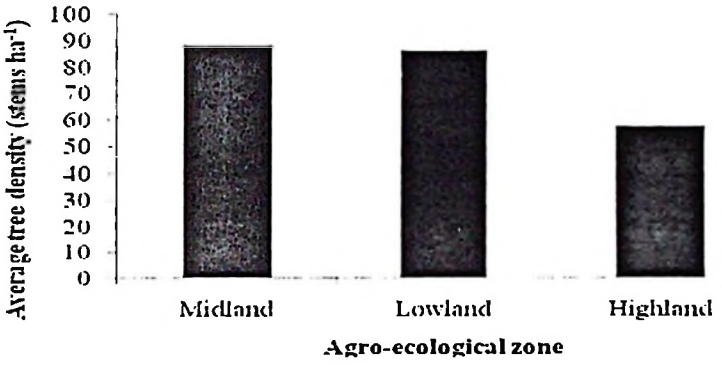

Figure 4: Tree density (Stems ha^{-1}) in different Agro-ecological zones in Moshi Rural District

4.2.2.3 Size structure

a) Basal area of trees

All villages are rich in trees with small DBH ≤ 40 cm. Individuals trees in this range in all villages are more than twice those in the DBH range between 40 and 60 cm D (Fig. 5). Trees with DBH ≥120 were rare in all agro-ecological zones (Fig. 5). The basal area of trees was 90 m^2ha^{-1}, 95 m^2ha^{-1} and 64 m^2ha^{-1} for highland, midland and lowland agro-ecological zones respectively.

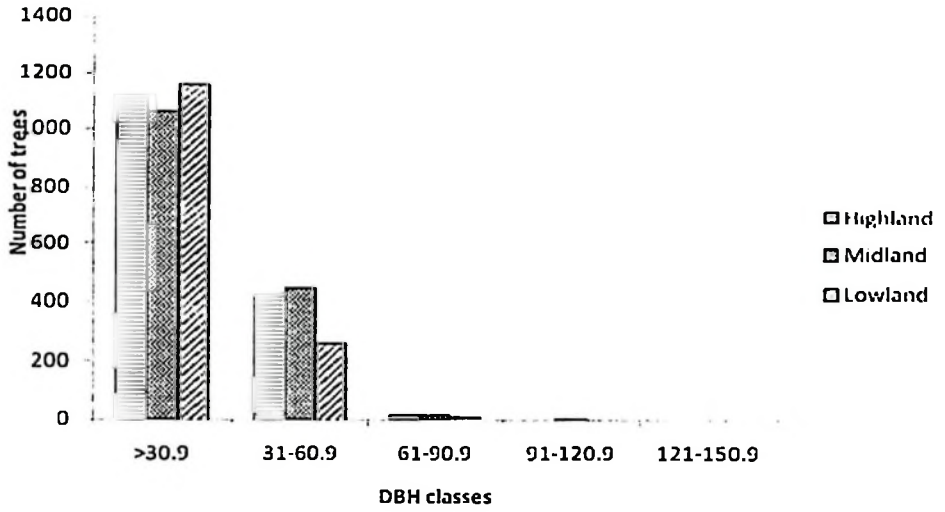

Figure 5: Trees density distribution by diameter for trees in homegardens of different agro-ecological zones of Moshi Rural District

4.2.3 Tree Species Richness and Diversity in Homegardens

The evenness (E) values of 0.38 to 0.52 indicated dominance of some tree species. The mean measure of evenness (E) was 0.44 with the highest tree species evenness in midland followed by lowland and lastly highland. Species richness was found to be higher in the lowland, followed by midland and lowest in the highland agro-ecological zone. The Shannon's index of diversity showed a mean value of 2.70 and its distribution was 2.21, 3.03 and 2.87 for highland, midland and lowland zones respectively. Simpson's index of diversity showed a mean value of 0.89 with the highest value from midland followed by lowland and lastly highland (Table 7). The value in the same column that followed by the same letter do not differ significantly based on Duncan's Multiple Range Test at 5%.

Table 7: Tree species' diversity and richness in sampled homegardens in three villages of Moshi Rural District (n=40)

Agro-ecoogical zone	Total number of tree species	Mean number of tree species	Number of trees per ha	Shannon Index (H')	Simpson Index (1-D)	Evenness (E')
Highland	24c	6.3c	2325c	2.21c	0.84c	0.38c
Midland	40b	10.9a	3553a	3.03a	0.93a	0.52a
Lowland	42a	8.2b	3498b	2.87b	0.90b	0.42b
LSD	0.123	0.023	0.121	0.003	0.006	0.001
CV (%)	0.2	0.1	0.0	0.0	0.3	0.1
F stat.	***	***	***	***	***	***

Key: $p < 0.001$ = ***

4.2.4 Species dominance

4.2.4.1 Dominance by family

Fabaceae was the most dominant family having 9 species followed by Euphorbiaceae (5 species), Rosaceae (5 species), Gramineae (4 species), Moraceae (4 species), Solanaceae (4 species), Anacardiaceae (3 species), Myrtaceae (3 species), Rutaceae (3 species). The remaining families contained 1 to 2 species (Appendix 1).

4.2.4.2 Tree Dominance by basal Area

Figure. 6, 7 and 8 show the dominance of different tree species by basal area in the highland, midland and lowland agro-ecological zones respectively. The most dominant trees in the district based on basal area are *Grevellia robusta, Albizia schimperiana, Persea americana* and *Manginifera indica* respectively. *Grevellia robusta* is the most dominant tree species in the highland and lowland agro-ecological zones while *Manginifera indica* is the dominant tree species in the midland agro-ecological zone.

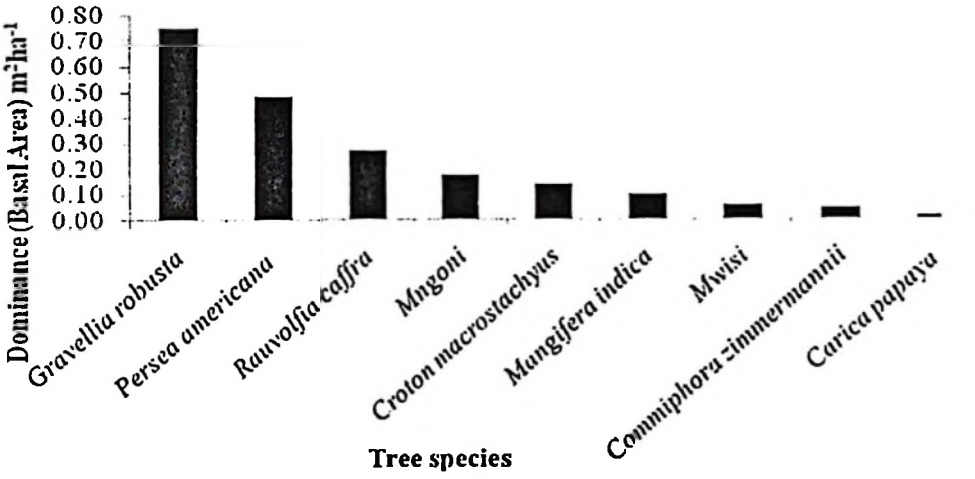

Figure 6: Tree species dominance by basal area in highland agro-ecological zone in Moshi Rural District

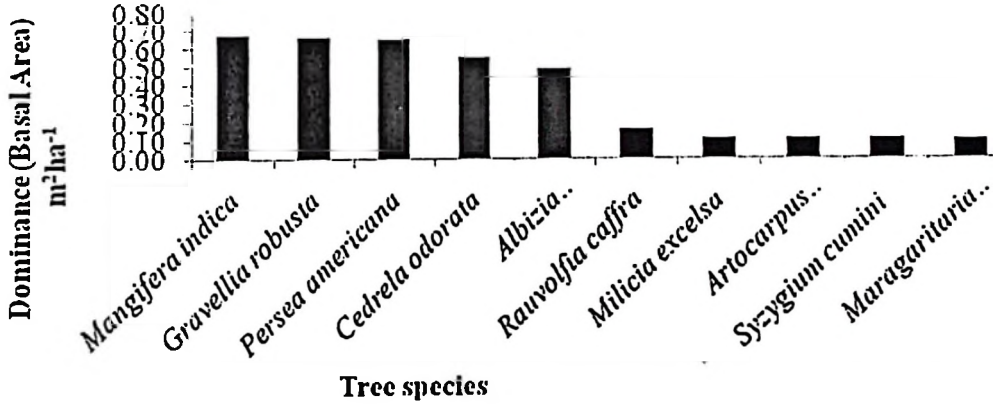

Figure 7: Tree species dominance by basal area in midland agro-ecological zone in Moshi Rural District

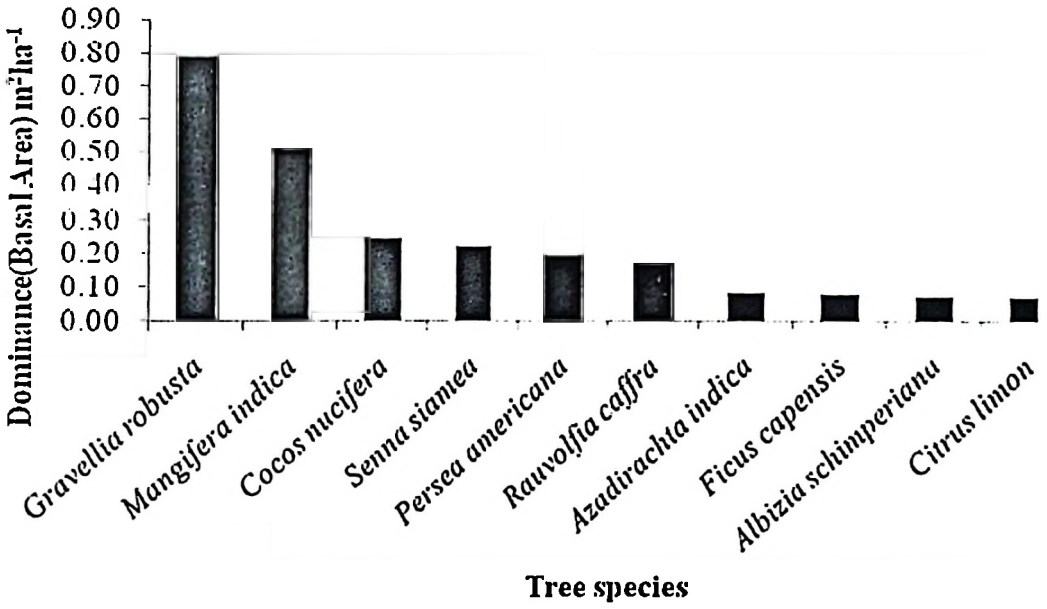

Figure 8: Tree species dominance by basal area in lowland agro-ecological zone in Moshi Rural District

4.3 The Changes in Composition of Homegardens Over Time

There has been a slight change in the composition of agroforestry homegardens in Moshi Rural District over the time period between 1980 to 2013. The components of the homegardens are the same as those recorded in previous studies by Fernandes *et al.* (1985), O'Kting'ati *et al.* (1984), Shayo (2005) and Soini (2002a). The changes that were observed in this study are the introduction of new crops and the change of the number of households having different components in their homegardens.

New crops that have been introduced in the homegardens include *Manihot esculenta* (cassava), and *Cajanus cajan* (pegion pea) due to their capacity to persist in drought conditions. Irrespective of the efforts of the Agriculture Extension Officers to encourage

farmers to plant these crops however the response has been low as only 12.5%, 10% and 17.5% of the respondents from the highland, midland and lowland agro-ecological zones respectively plant them. Livestock found in the homegardens during this study are the same and they have not changed with time. The change in the number of households keeping livestock and other components is indicated in Tables 8 to 10.

Table 8: Proportion of farmers having different components in their homegardens in different time frames in highland agro-ecological zone in Moshi Rural District (n=40)

Component	Percentage of farmers in Time frame Current				
	1980	1990	2000	2010	(2013)
Coffee	100	100	95	90	90
Maize	100	100	97.5	95	97.5
Beans	100	100	97.5	97.5	97.5
Yam	100	95	75	62.5	50
Sweet potatoes	65	60	60	45	22.5
Vegetable	100	100	82.5	50	50
Bananas	100	100	100	95	97.5
Livestock	100	100	87.5	95	90
Beekeeping	10	10	10	7.5	15
Cassava	0	0	0	0	2.5
Cowpea	0	0	0	2.5	7.5

Table 9: Proportion of farmers having different components in their homegardens in different time frames in midland agro-ecological zone in Moshi Rural District (n=40)

Component	Percentage of farmers in Time frame			Current	
	1980	1990	2000	2010	(2013)
Coffee	75	62.5	50	42.5	22.5
Maize	97.5	97.5	97.5	97.5	97.5
Beans	100	80	92.5	97.5	97.5
Yam	100	100	57.5	30	12.5
Groundnuts	20	20	7.5	0	0
Vegetable	100	100	90	70	50
Bananas	90	85	80	60	52.5
Livestock	95	75	87.5	77.5	77.5
Beekeeping	40	27.5	12.5	12.5	10
Cassava	0	0	0	7.5	7.5
Cowpea	0	0	0	0	2.5

Table 10: Proportion of farmers having different components in their homegardens in different time frames in lowland agro-ecological zone in Moshi Rural District (n=40)

Component	Percentage of farmers in Time frame Current				
	1980	1990	2000	2010	(2013)
Coffee	65	65	17.5	10	5
Maize	100	100	100	100	100
Beans	100	100	95	95	95
Yam	80	67.5	35	22.5	5
Groundnuts	90	75	75	52.5	57.5
Sunflower	0	0	32.5	25	12.5
Bananas	100	100	72.5	50	30
Animals	92.5	75	95	90	87.5
Bee keeping	25	25	20	12.5	7.5
Pegion pea	0	0	10	10	15
Cowpea	0	0	0	7.5	2.5

4.4 The livelihood assets of Moshi Rural District homegardens

4.4.1 Human Capital

Most of the households' head (42%) were above 55 years (Table 11). Most of the farmers have finished seven years of primary education (Table 12). The average size of interviewed households is 5.1 (Table13).

Table 11: Age class distribution in Moshi Rural District households' (n=120)

Age Class	Percent
15-24	2.5
23-34	5.8
35-44	14.2
45-54	35.0
55 plus	42.5
Total	100.0

Table 12: Level of education of households' head in Moshi Rural District (n=120)

Level of education	Percent
No formal education	10.0
Primary	57.5
Secondary	26.7
Diploma	5.8
Total	100.0

Table 13: Number of people per household in Moshi Rural District (n=120)

Number of people in household	Percent
1-5	61
6-10	36
11-15	3
Total	100

4.4.2 Natural Capital

Land

The average size of homegardens in the study area are 0.78 ha, 0.51 ha and 0.49 ha in the highland, midland, and lowland zones respectively (Fig. 9).

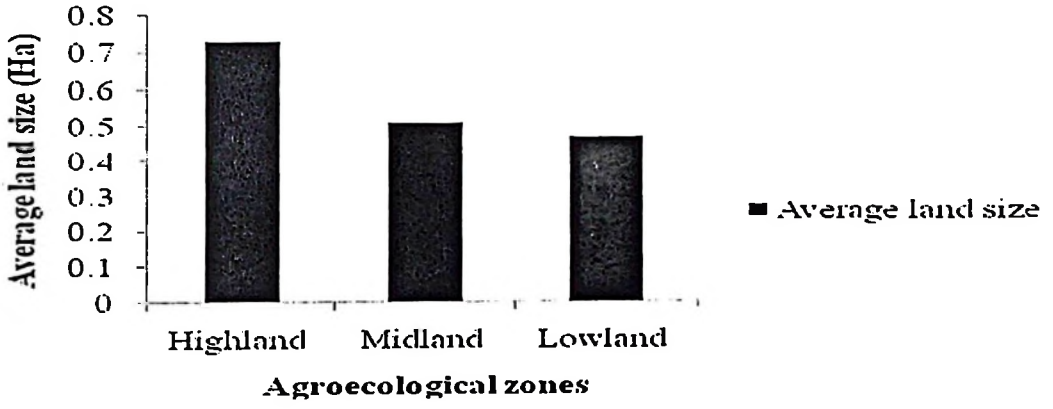

Figure 9: Average land sizes of Agroforestry homegardens in the agroecological zones of Moshi Rural District

4.4.3 Financial Capital

4.4.3.1 Crop production

Crops that are commonly grown in the homegardens of Moshi Rural District are maize, beans, coffee, bananas, various vegetables and groundnuts. Maize is a crop with highest yield followed by livestock products, beans, coffee and groundnuts. Bananas are grown in large amounts in the highland followed by midland and lastly lowland. The average yield of banana bunches is very hard to obtain since they are available throughout the year and

many farmers harvest the ones that have matured and use them in the family without keeping records.

The average yield of maize in the studied villages is 1049 kg ha^{-1}. The production in the highlands varies between 30 kg ha^{-1} to 988 kg ha^{-1} with an average of 271 kg ha^{-1}. In the midlands the annual harvests vary from 98 kg ha^{-1} to 3706 kg ha^{-1} with the average being 1016 kg ha^{-1}. In the lowland they vary between 197 kg ha^{-1} to 5930 kg ha^{-1} with an average of 1783 kg ha^{-1} . The average annual yield of beans is 274 kg ha^{-1} with Lowland being the highest producer of 487 kg ha^{-1} and the midland and highlands producing 212 kg ha^{-1} and 121 kg ha^{-1} respectively.

The average yield of coffee in the district was 118 kg ha^{-1} with highlands producing 121 kg ha^{-1}, midlands 119 kg ha^{-1} and lowlands 24 kg ha^{-1}. The estimated average yield of bananas per year was 115 bunches ha^{-1} with the highlands producing 117 bunches ha^{-1} followed by midland with 57 bunches ha^{-1} and lastly the lowlands production of 38 bunches ha^{-1}.

Other crops recorded were pigeon peas and groundnuts. Pigeon peas were grown in the midlands and lowlands with the average yield of 414 kg ha^{-1} with the lowland producing 499 kg ha^{-1} and midland producing 158 kg ha^{-1}. Groundnuts were grown in lowland agro-ecological zone alone and the average yield per year was 251 kg ha^{-1}.

4.4.3.2 Livestock production

The livestock that were found in the homegardens were mostly for home consumption. The income from livestock is mainly from selling cattle milk, other sources are selling pigs, extra eggs, and rarely from selling goats and sheep that are sold when there is urgent

need of money. The average milk production is 907 litres year^{-1} with 920 litres from the highlands, 816 litres from the midland and 954 litres from lowland agro-ecological zones. When the farmers were asked on the trend of productivity of their farms for the past 10 years 66.7% of the respondents from all agro-ecological zones agreed to be decreasing, 15% increasing, 15.8% constant and 2.5% did not know.

4.4.3.3 Food security

Food security in the interviewed households was obtained by asking respondents whether the food obtained from the agroforestry homegardens are enough to sustain the family for the whole year and the results are presented in Table 14.

Table 14: Respondents view on availability of food in the family for the whole year in different agro-ecological zones of Moshi Rural District (n=40)

		Households responses to food sufficiency based on the Agroforestry product (%)		Total
		Yes	No	
Agro-ecological zones	Highland	55	45	100
	Midland	73	27	100
	Lowland	60	40	100
	Average	63	37	100

4.4.3.4 Marketing crops

Hundred percent of people who were interviewed responded that there is market for all their products. Thirty five percent of the respondents do not sell their products, 32.5% sell at the local market in their villages twice per week, 14.2% sell to their neighbours, 12.5% sell in the farmers associations and 5.8% sell to the traders who directly buy from their farms.

4.4.3.5 Income generated from Agroforestry homegarden products

The income generated in the study area comes from the sales of beans (16.6 %), bananas (11.5%), coffee (8.7%), groundnuts (4.3 %), maize (27.4%), and milk (31.5 %) (Table 15). For other products like vegetables and fruits it was difficult to calculate the amounts of money obtained by farmers because they do not keep records of how much they harvest and the amount they sell.

When asked to rank the first, second and third most profitable products, many respondents from the highland agro-ecological zone named coffee as their first profitable, bananas the second and livestock and vegetables the third profitable. Midland respondents named maize to be the first, beans the second, bananas and fruits together the third most profitable products. In the lowland zone maize, beans and groundnuts was the first, second and third most profitable products respectively.

Table 15: Average production, sales and income generated of products in the agroforestry homegardens of Moshi Rural District

Product	Production (kg)	Quantity sold	Average Price T.sh	Annual income generated T.sh	% of income generated
Milk**	2689	2381	1000	2 381 000	31.5
Maize	3087	2758	750	2 068 500	27.4
Beans	923	795	1575	1 252 125	16.6
Bananas*	279	162	5375	870 750	11.5
Coffee	306	264	2500	660 000	8.7
Groundnuts	250	211	1525	321 775	4.3
Total				7 554 150	100

*bunches
**Litres

4.4.3.6 Fuelwood

The main source of cooking energy is fuelwood which is obtained from the trees in the homegardens and from the nearby forests. Results on the availability of fuelwood for household consumption for the whole year are presented in Table 16.

Table 16: Respondents view on fuelwood availability to household over the year (n=120)

Fuelwood availability to household over the year	Frequency	Percent
Yes	35	29.2
No	85	70.8
Total	120	100.0

CHAPTER FIVE

5.0 DISCUSSION

5.1 Agroforestry systems and technologies practiced in the homegardens of the local communities in Moshi Rural District

The results on Agroforestry systems and technologies practiced in the homegardens of the local communities in Moshi Rural District are presented in Table 2 and Fig. 1. It was observed that Agrosilvopastoral systems was a widely practiced system in all surveyed villages, a finding that concurred with Nair (1993) who stated that most homegardens are Agrosilvopastoral systems consisting of herbaceous crops, woody perennials and animals. Agroforestry technologies practiced were mixed intercropping, live fence and boundary planting. Mixed intercropping was practiced by every household as they mix herbaceous crops and trees and shrubs in the same land. Coffee and banana plants were planted in straight lines and other crops like yams, potatoes, maize and beans planted in empty spaces between coffee and bananas. Trees are also planted in between to provide shading to coffee and other crops.

Live fence technology was mostly practiced in highland agro-ecological while boundary planting was highly practiced in midland and lowland. *Dracaena afromontana* and *Bougainvillea spectabilis* are among the plant species that are widely used as live fences and *Grevillea robusta*, *Persea americana*, *Tripsacum laxum and Polyalthia longifolia* were planted for boundaring.

5.2 The composition, Tree Structure and Tree Diversity of Agroforestry homegardens

5.2.1 The composition of agroforestry homegardens

Components of the agroforestry homegarden recorded during this study are the same as those recorded by Baijukya *et al.* (2004); ICRAF (2009); Kaihura *et al.* (2001); Makawia (2004); Moshi (1997); Rweyemamu (2001); Shalli (2003); and Shayo (2005) in different homegardens in Tanzania.

Maize and beans are common in almost all farms (Fig. 2) because they contribute to daily diet of the farm family and high market demand. Occurrence of banana decrease from highland to lowland, it used to be the staple food of the Chagga people but its production across the zones has decreased due to decreased availability of water. Construction of infrastructures like tarmac roads has affected the natural flow of water and causes people from one side of the road in midland zone to be disconnected from the natural streams and rivers hence lower the production of bananas, vegetables and yams that need plenty of water. Groundnuts (*Arachis hypogaea*) were found to be grown by many farmers in the lowland but were not grown in highland and midland. In highland and midland zones the farms are highly concentrated with coffees which leave no space for groundnuts that were recorded in lowland zone where many farms do not have coffee trees.

The same types of crops are found in other agroforestry homegardens in Tanzania like the highland zone Kigoma homegardens, Kagera homegardens (Rugalema *et al.*, 1994a, b) and West Usambara homegardens (Moshi, 1997). Kebebew *et al.* (2011) recorded the same number of cultivated crops in agroforestry homegardens of Jimma, Ethiopia with herbaceous crops such as maize, banana, taro, sweet potatoes and maize that are common in the Chagga homegardens being common in Jimma too.

This study found that chicken comprises the highest population among other animals in homegardens (Appendix 5). The highest population of chicken is due to the fact that they are local breeds which are free range. In Ukerewe and Kibaha homegardens, chicken were also dominating the livestock population followed by other animals (Rweyemamu, 2001; Shalli, 2003). In Arumeru homegardens, cattle comprised the highest population followed by chicken, goat, rabbit and pigs (Makawia, 2004).

In all zones livestock were found to be kept under stall-feeding, a situation that is different from what was reported by Soini (2002a, b) who stated livestock in the highlands were the one kept under stall-feeding and in the lowlands free-range livestock keeping was practiced. Livestock and their products have important roles in generating cash, nutrition and maintaining the productivity of the farmland.

Many people have stopped keeping beehives compared to the year 1985 because according to Fernandes *et al.* (1985) many farmers kept between three to five traditional beehives, and it was conservatively estimated that each hive produces at least 5 kg of honey per year while this study revealed that only 15, 10 and 7.5 percentages of households in highland, midland and lowland respectively are engaging in beekeeping and the average number of beehives per household is 3.3, 3 and 1.5 for highland, midland and lowland respectively.

Many tree species that are widely used in the Chagga homegardens are among the best bee-fodder tree species. Examples of the trees are *Albizia schimperiana, Cordia africana, Gravellia robusta, Mangifera indica* and *Rauvolfia cafra*. This is a great opportunity for every household to engage in beekeeping due to presence of those trees in almost every homegarden.

Irrespective of many natural streams of water in the highland agro-ecological zone, there were no natural or constructed fish ponds recorded during this study, only one fish pond was recorded in lowland agro-ecological zone (Table 6). This shows that people do not use the available natural resources to get extra source of money instead of depending on agriculture whose production is declining. This is caused by lack of capital and education on fish farming.

5.2.2 Tree structures and diversity of homegardens in Moshi Rural District

The tree structures of homegardens were categorized into vertical and horizontal structures whose results are presents in Figs. 4 to 8 and Table 7. The vertical stratification in the Chagga homegardens has not changed overtime as it is the same as the one recorded by Fernandes *et al.* (1985) and is the same as the one recorded in other homegardens by Moshi (1997), Albuquerque *et al.* (2005) and Ffolliot (2005). The vertical stratification of homegardens provide gradient in light and relative humidity, which creates different niches for enabling various species groups to exploit them (Kitalyi *et al.*, 2013).

The midland agro-ecological zone was found to have the highest tree density followed by lowland and lastly highland zone (Fig. 4). One of the reasons that might have caused the highland zone to have the lowest mean tree density is the presence of coffee trees in the farms that were not included in the determination of density. The mean tree density recorded in Moshi Rural is lower than that of Rombo District recorded by Shayo (2005) but higher than that of West Usambara's homegardens recorded by Moshi (1997). These results contrast with Fernandes *et al.* (1984) who observed the lowland belt to have very few trees. These results concurred with those of Kumar (2011) in India who found that

tree density (per hectare) were highest for small-sized holdings while large-sized homegardens had more stems per garden.

The total number of plants species recorded was 83 that were distributed among 40 families in the three studied villages (Appendix 1). The number of species is higher than that from Rombo District homegardens where Shayo (2005) recorded 66 and 74 species in the upper and middle zone respectively which belonged to 30 and 32 families in the upper and middle zone respectively.

Homegardens have been acknowledged to have high conservation value since it is estimated that forest species in the Chagga homegardens contribute about 17% of the forest plants of Kilimanjaro (Kitalyi *et al.*, 2013). Since the homegardens were part of the forest cover, the forest related trees recorded during this study were the remaining of *Albizia schimperiana, Rauvolfia caffra, Commiphora eminii, Cordia africana,* and *Margaritaria discoidea.* There are also introduced timber trees such as *Cedrela odorata, Grevillea robusta* and *Cupressus lusitanica* and fruit tree species such as *Persea americana, Mangifera indica* and *Syzygium cumini.*

Most of the tree species found in the homegardens is timber trees followed by fruit trees. Usefulness of trees in the Chagga homegarden differs with Moshi (1997) and Albuquerque *et al.* (2005) who recorded most of the trees to be used for medicinal purposes followed by timber and ornamental. Akinnifesi *et al.* (2010) recorded a different scene whereby 61.8% were fruit tree species, 7.5% were medicinal plants, 6.4% were timber trees and the remaining 7.7% were plants of miscellaneous use. A different scene was also recorded in West Java by Kumari *et al.* (2009) where most of the trees were used for ornamental followed by fruits, vegetables, building materials and fuel wood

respectively. Most of the fruit trees recorded in Table 3 are similar with those recorded by Moshi (1997) in West Usambara homegardens.

The diversity of woody perennial component in the Chagga homegardens contributes to the social and economic sustainability of this system by providing shading, fuelwood, timber, medicine, ornaments and income generation through selling fruits and other products. The plants species found in the homegardens have the wide range of uses as those recorded by Maroyi (2009) in Zimbabwe. Different studies have acknowledged the importance of homegardens in fulfilling the social and economic needs of the family hence enhancing conservation of plant diversity (Devi and Das, 2012).

Fabaceae is the most dominant family in this study as it has plant species for almost all uses including timber, medicinal, food, fodder, ornamental and fuel wood plants hence the people prefer them. The study by Molebatsi *et al.* (2010) in South Africa also recorded Fabaceae to be the most dominant family while Lengkeek *et al.* (2005) recorded Rubiaceae as the most dominant family.

The results in Fig. 5 indicate that 81.1%, 71.9% and 69.5% of trees belonged to the lowest DBH class from lowland, highland and midland respectively which indicate that many trees in the study site are young trees from 1 to 10 years that may also indicate adequate regeneration of trees in the homegardens. The DBH class of 91-120.9 cm comprise of 0.1%, 0.2% and 0.3% of trees in the lowland, highland and midland respectively, this indicate indigenous large trees have been harvested from the homegardens. The distribution of stems by diameter follows the usual reverse J shape with more stems in the lower diameter classes.

The highest mean basal area was recorded in midland agro-ecological zones followed by highland and lowland. Similar observations were reported by Shayo (2005) who observed the middle zone homegardens to be having higher basal area compared with the upper zone homegardens. The results on relationship between basal area and DBH class comprehend with Dissanayake and Hettiarachchi (2013) who stated that highest basal areas can be recorded in fewer large size individual trees.

The basal areas cover of the Moshi Rural District homegardens is lower than that of Rombo District homegardens (Shayo, 2005) but higher than those recorded by Das and Das (2005) in Assam homegardens.

Mean number of tree species per farm was 8.6 with 42% of the homegardens having more than 8 tree species. The figures are low compared to the mean of 21 tree species that was recorded in Southern Ethiopia and 20 tree species in North India homegardens with land size less than 1 ha. (Abebe, 2005; Das and Das, 2005).

On the whole, mean evenness of tree species was 44% of what it could have been under uniform distribution, this means the relative homogeneity of the species in the samples is 44% of the maximum possible even population, and some species are thus more abundant than others. The results show that the pattern of Evenness values (E) corresponds with Shannon and Simpson values as it shows Midland Agro-ecological zone has the highest values while Highland Agro-ecological zone has the lowest values. Farms in midland have the highest diversity Index because it has the highest mean number of species and Highland Agro-ecological zone has low diversity as it has few tree species. The diversity indices for tree species generally showed that few species are more abundant than the others.

Grevallia robusta is the dominant tree specie in highland and lowland zones while *Mangifera indica* is dominant in midland agro-ecological zone. This is because *Gravelia robusta* has been grown as a shade tree in coffee farms in the area for a long time and coffee was widely grown in both zones. *Persea americana* is the second dominant in the highland and midland zones as it is a multipurpose fruit tree used for food, fodder, shade and timber.

The results of dominance of *Grevallia robusta* trees in the highland and lowland zones in this study are in agreement with the findings of Soini (2002a) who indicated it to be dominating in both highland and midland zones but the dominant tree species in the lowland *Manginifera indica* is the same in all studies.

5.3 The changes in Composition of Homegardens Over Time

The components that are currently grown in agroforestry homegardens are not different from those grown in the past. All households interviewed revealed that components that are currently found in their farms are the same as what was present in the past (Tables 8 to 10). Current results indicate that there are some of the species that are lost from the Chagga homegardens since Fernandes *et al.* (1985) identified a total of 111 plants species spread over 42 families, they included 53 tree species, 29 food crop species, 21 economically useful non-woody plant species and 8 weed species while this study recorded 86 plant species.

According to Soini (2002b) crops that were grown in the middle belt and lowlands were maize and beans, which are often intercropped, other crops include sunflower, finger millet, groundnuts, banana, cassava, sweet potatoes and vegetables like tomato, onion, cabbage, eggplant and spinach.

Though the components of the homegardens are still the same but the number of people keeping the components has changed with time. This study revealed that more cattle are kept in highland followed by lowland and lastly midland with the average of 2 cows per household in all agro-ecological zones, 42% of the interviewed households in the highlands had cattle. But Soini (2002a) recorded more cattle on the lowland with 6 cows per farm and in the highlands 1 cow per farm with 50% of the interviewed household were keeping cattle.

In case of goats, these results comply with Soini (2002a) as lowland agro-ecological zone has more goats compared to highland agro-ecological zone. The difference is with the average number of goats per household across the zones, in this study the average number of goats per household was 4 in all zones while Soini (2002a) recorded 1 to 2 goats in highland and 8 goats in lowland agro-ecological zone.

The Chagga homegardens are not the only ones that have changed over time in Tanzania since Baijukya *et al.* (2004) revealed that during the period of 1961 to 1999 the Homegardens in Bukoba had changed in the cropping pattern. Homegardens in Nepal and Ethiopia have also been transformed over time that lead to disappearance of many important and useful plant species (Pulami and Paudel, 2006; Gebrehiwot, 2013).

5.4 The Livelihood Assets of Moshi Rural District Homegardens

The results in Table 12 indicate that large numbers of households in the study area are managed by older people than the youths. The older age group is considered as people with experience and valued accumulation of homegarden management technologies. The size of the family was between 1 and 15 members with the average of 5.1 which is lower than that of 6 recorded by Soini (2002a) and Kebebew *et al.* (2011), Shayo (2005)

recorded an average of 8.3 people in Rombo homegardens. Different studies indicate that the sizes of the households are decreasing with time from those recorded by Fernandes *et al.* (1985) of 9.9 people, to those of Soini (2002a) of 6 people and those of the presents study of 5.1 people. Although, unfortunately it was not determined, the current results might also be indicating a greatly or rapidly decreasing rate of household workforce availability. According to Fernandes *et al.* (1985) a household with an average size of 9.9 people, provided a workforce of four family members.

The average land size per household is also rapidly decreasing from that recorded by Fernandes *et al.* (1985) of 0.68 ha from that recorded by Soini (2002b) of 0.6 ha and the present land size of 0.57 ha. Fernandes and Nair (1986) and the present study stated homegardens being smaller than one hectare were typical of subsistence agriculture. Even now, however the sizes of the homegardens in Moshi Rural District are higher than those of Sri Lanka that average 0.3 ha (Senanayake *et al.*, 2009).

Maize production of 1049 kg ha^{-1}, with the lowlands having higher yield followed by those of the midlands and lastly the highlands are higher than those reported by Fernandes *et al.* (1985) for the lowland of 360 kg ha^{-1} per year but lower than those averaging 2280 kg ha^{-1} from yields of 350 kg ha^{-1} to 6000 kg ha^{-1} reported by Soini (2002b) for the same lowlands and midlands. Coffee have been a commercial crop of the Chagga people for a very long time whereby it is tended by fathers in the households from production to the harvest stage and he sell it and have total control of the money obtained from the crop. Its harvest has been decreasing to cause more people to stop caring the coffee plants and some of them to completely remove the coffee trees from their farms and plant other crops which are more valuable to them at the time. Reasons given by the farmers for the decrease in coffee production were diseases such as coffee berry, increase in production

costs and decrease in coffee prices which made many farmers lose their invested money instead of getting profits. Soini (2002b) recorded coffee yields of only 270 kg ha^{-1}, while the production potential was between 500 kg ha^{-1} to 750 kg ha^{-1} (Soini, 2002b).

The number of households planting coffee was indicated to be decreasing from the highlands to the lowland agro-ecological zones. Trend of production along Agro-ecological zones do not vary from those recorded by (O'kting'ati and Kessy, 1991) who characterized lowland farming system as intensive and mechanized of the three farming system.

The primary function of many tropical homegardens is food production as many of the crops are subsistent with exception of those with cash crops like coffee and cocoa. This study found that only 63% of agroforestry homegardens are capable of providing food for the household for the whole year. When comparing the agroforestry homegardens of Batticaloa District in Sri Lanka and the Moshi Rural District homegardens which are both which are multi layered the latter is performing well as Krishnal *et al.* (2012) only 23.3% of homegardens to be in food secure condition.

The market of the products is no longer the problem since the villages are easily accessible through roads. Most of the people sell their products in the neighbouring markets. Crops that are mostly sold from the highland agro-ecological zone are coffee, bananas and excess maize and beans. In the midlands the most sold crops are maize, beans, livestock and livestock products and fruits. In the lowlands the most sold crops are maize, beans, fruits and groundnuts. Most of the coffee produced in the Chagga homegardens is for sale a situation similar to that of Sidama Southern Ethiopia (Abebe *et al.*, 2010) but different with that of Jimma Southwestern Ethiopia where it is for

consumption (Kebebew, 2011). In general, livestock and their products made the highest income (31.5%) followed by maize (27.4%) and other crops as indicated in Table 14. These observations are different from those recorded by Meena and Okefe (2007) in Moshi Rural and Rombo Districts in the year 2006 whereby the income generation in those districts was comprised primarily from coffee (15%), bananas (28), milk sales (7%), livestock sales (4%), remittances (17%) and off-farm sources of income (27%).

Meena and O'Keefe (2007) reported that 98% of households in Kilimanjaro Region homegardens depended on fuelwood as the primary source of energy for cooking and lighting. Shayo (2005) reported the homegarden to be the major source of firewood whereby it contributed 66% and the remaining 34% was collected from nearby forests and woodlands. The above findings means there is high dependence on woody perennials and herbecious crops from the homegardens for meeting the fuelwood needs of the communities. This study, however, found that only 29.8% of the respondents meet their fuelwood requirements from the homegardens. It is therefore very clear that there is a considerable dependence on other sources like the reserved forests. The time taken to fetch fuelwood can therefore significantly impact on the time available for other productive, and potentially income generating, activities.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

This study concludes that;

There are five agroforestry systems practiced in the surveyed villages of Moshi Rural District with Agrosilvopasture being the most widely practiced system followed by Agrosilviculture, Agroaposilvopasture, Agroaposilviculture and Agroaquo silvopasture system. The technologies that are practiced in the agroforestry homegardens are Mixed intercropping, Live fence and Boundary planting.

Agroforestry homegardens were found to comprise of herbaceous crops, livestock, insect and fish that were under various interactions with woody perennials. A total of 87 plant species comprising of 64 species of woody perennials and 23 herbaceous crops, 6 animal species, bees and one fish type were recorded in all agro-ecological zones of Moshi Rural district.

Spatial arrangement of homegardens in all zones was irregular and random but the vertical arrangement was obvious and clearly recognizable with 4 storey strata. The density of trees was high in the midland followed by lowland and low in the highland. Basal area was high in the midland followed by highland and lastly lowland. Tree species richness was higher in the lowland followed by midland and highland had lower richness than other agro-ecological zones. The results show that the pattern of Evenness values (E) corresponds with Shannon and Simpson values as it shows Midland Agro-ecological zone has the highest Evenness, Simpson and Shannon values and Highland has the lowest Evenness, Simpson and Shannon values. Fabaceae was the

dominant family having 9 species followed by Euphorbiaceae and others. The most dominant trees in the district based on basal area of trees are *Gravellia robusta, Albizia schimperiana, Persea americana* and *Manginifera indica* respectively. *Gravellia robusta* is the dominant tree species in highland and lowland agro-ecological zones while *Manginifera indica* is the dominant tree species in midland agro-ecological zone.

There is a slight change in composition of agroforestry homegardens in the time period of the year 1980 to present, the components of the homegardens are almost the same with introduction of few crops and trees. Changes that can be observed are the numbers of households having certain components in their farm and the number of livestock owned by the household.

Many homegardens are managed by older people aged above 55 years with the majority of household heads having at least primary education. Only 10% of all of the households' heads had no formal education. The average size of the family is 5.1 that can affect the available workforce of the family. The average size of the family is 0.57 ha that has decreased comparing to 0.68 ha that was recorded in the year 1985. Crop production is decreasing and the reasons given by farmers are decreasing rainfall, high cost of agricultural inputs, low prices of crops especially coffee and lack of enough man power.

6.2 Recommendations

i. Farmers must add more components in their systems so as to diversify their products rather than depending on herbaceous crops and trees. Trees that are planted in the homegardens are suitable for bee keeping so farmers are to be encouraged to have bee hives in their homegardens in order to get products that can be for home consumption or selling to get extra income to buy food and other

necessities. In the highland agro-ecological zone where natural water is still flowing and other zones the people have to be educated how to start and operate fish ponds so as to make use effectively the resources surrounding them.

ii. In the highland soil has lost its fertility due to soil erosion that is caused by application of technologies that do not prevent soil erosion. Many people have to be encouraged to use other technologies such as alley cropping that prevents soil erosion. Adoption of fodder bank technology that ensures availability of nutritious rich leguminous leaves for ruminant animals during wet and dry season is to be encouraged. Trees that are efficient in nitrogen fixation have to be introduced in the homegardens to rejuvenate the soil.

iii. Since many households depend on firewood as source of cooking energy and they cannot get enough firewood from their homegardens, other source of fuel must be sought instead of highly depending on fuel woods. Firewood efficient stoves have to be introduced so as to reduce the amount of firewood used by the households.

iv. Coffee has been back bone of many homegarden owners but it is facing many problems that lead to low yield that cause many farmers to stop caring for them or removing them in their gardens. More efforts have to be done to provide the improved seedlings from TACRI and educate farmers on the effective usage of growing inputs so as to produce organic coffee that is sold at high price comparing with normal coffee.

v. In the lowland agro-ecological zones, farmers were encouraged to plant drought tolerant crops in their farms like sorghum and maize breeds that grow for a short

period of time but their response was low. More emphasis has to be made so as to cope with the current situation.

vi. High cost of agricultural inputs was stated to cause low production, people have to keep more cattle so as to get manure that can increase crop production while reducing production costs.

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APPENDICES

Appendix 1: Plant species that were found in the homegardens

Family Name	*Botanical Name*	Common Name	Venacular Name	Uses
Amaranthaceae	*Amaranthus Spp*		Mchicha	Vegetable
Anacardiaceae	*Anacardium occidentale*	cashew	Mkorosho	Edible fruit and seed, fuelwood
	Mangifera indica	Mango	Mwembe	Edible fruit, fuel wood
	Sorindeia madagascariensis		Mgweda	Edible fruits
Annonaceae	*Polyalthia longifolia*	False Ashoka		Ornamental
Apocynaceae	*Rauwolfia caffra*		Msesewe	Timber, fuelwood, catalyst for brewing, medicinal
Aracaceae	*Cocos nucifera*	Coconut	Mnazi	Edible fruits
Araceae	*Colocasia esculenta*	Taro	Maduma	Edible roots
Asteraceae	*Helianthus annuus*	Sunflower	Alizeti	
Bignoniaceae	*Jacaranda acutifolio*			Shade, fuelwood, ornamental
Boraginaceae	*Cordia abyssinica*		Mringaringa	Timber, fuelwood,shade, fodder
	Markhamia platycalyx		Mtarawanda	Timber, fuelwood, poles
Burseraceae	*Commiphora zimmermannii*		Mfifina	Fodder
Caricaceae	*Carica papaya*	Pawpaw	Mpapai	Edible fruit
Combretaceae	*Terminalia superba*		Mti kivuli	Timber, ornamental
convolvulaceae	*Ipomea batatas*	Sweet potatoes	Shisowia	Edible roots, vegetable
Cruciferae	*Brassica carinata*	Abyssinian mustard	Loshuu	
Cucurbitaceae	*Telfairia pedata*		Makungu	Fat from seed
Cupressaceae	*Cupressus lusitanica*	White cedar		Ornamental, timber
Dioscoreaceae	*Dioscorea elata*	Yam	Ngao, shia	Edible tubes
	Dioscorea bulbifera	Yam	Nduu	Edible tubes
Euphorbiaceae	*Bridelia micrantha*		Mmarie	Fuelwood, poles, withies, fodder
	Croton macrostachyus		Mfurufuru	Shade, fuelwood, goat fodder
	Jatropha curcas		Mchimba kaburi	Boundary, grave marking
	Manihot esculenta	Cassava	Muhogo	Edible root, vegetable
	Maragaritaria discoidea		Mshamana	Fuelwood, poles, fodder
Fabaceae	*Acacia totilis*	Umbrella thorn	Mgunga	Timber,fodder, gum, medicinal
	Acacia xanpholea	Fever tree	Mnera	
	Arachis hypogaea	Peanut	Karanga	Edible seeds
	Cajanus cajan	Pigeon pea	Mbaazi	Food, forage
	Dalbergia melanoxylon	African blackwood	Mpingo	Timber
	Leucaena leucocaphala	White leadtree	Mkusina	Fodder, green manure
	Senna siamea	Cassod tree	Mjohoro	Shade, fodder, windbreak, fuelwood
	Senna singueana		Mtogo	Ornamental
	Tamarindas indica	Tamarind	Mkwaju	Edible fruit, fuelwood
Gramineae	*Saccharum officinarum*	Sugar cane	Miwa	Edible stem
	Tripsacum laxum	Guetamala grass		Fodder
	Vetiveria zizanioides	vetives	Khuskhus grass (manzao)	Thatching, anti-erosion
	Zea mays	maize	Mahindi	Staple food, fodder
Lauraceae	*Ocotea usambarensis*	East African camphorwood	Mkulo	Timber
	Persea americana	Avocado	Mparachichi	Edible fruit, shade, fuelwood, fodder
Leguminoseae (mimosoideae)	*Albizia gummifera*	Peacock flower	Mfuruanje	Fuelwood, fodder, timber
	Albizia schimperiana		Mruka	Fuelwood, shade
	Newtonia buchannanii		Mkufi	Timber, shade, fuelwood

Family Name	*Botanical Name*	Common Name	Venacular Name	Uses
Leguminoseae (papilionoideae)	*Phaseolus vulgaris*	Beans	Maharagwe	Food
	Vigna unguiculata	Cowpea	Kunde	Food
Liliaceae (Alloideae)	*Allium cepa*	Onion	vitunguu	Spice
Liliaceae (Dracaenoideae)	*Dracaena afromontana*		Masale	Fence, boundary marking and grave marks
Lythraceae	*Punica granatum*	Pomegranate	Mkomamanga	Edible fruit
Magnoliopsida	*Terminalia catappa*	Tropical almond	Mkungu	Edible fruit, fuelwood, shade, timber
Malvaceae	*Adansonia digitata*	Baobab	Mbuyu	Edible fruit, fodder,
Meliaceae	*Azadirachta indica*	Neem	Mwarobaini	Shade, medicinal
Moraceae	*Artocarpus heterophyllus*	Jack fruit	Mfenesi	edible fruits, fuelwood
	Ficus capensis		Mkuyu	
	Ficus exasperata	Fig	Msasa	Shade, fuelwood
	Ficus natalensis		Mfumu	Shade, ritual tree
	Milicia Excelsa	African teak	Mvule	Timber
Moringaceae	*Moringa oliefera*	Moringa	Mronge	Medicinal
Musaceae	*Musa nana*	Banana/ plantain	Kinguruwe	Edible fruits, fodder
	Musa paradisiae		Mshare	
Myrtaceae	*Psidium guajava*	Guava	Mpera	Edible fruit, fuelwood
			Mwisi, mmasi	Edible fruit, fuelwood, fodder
	Syzygium cumini	Jambul	Mzambarau	Edible fruits, medicinal, timber
	Zyzygium guineense	Waterberry	Zambarau mwitu	Edible fruit, medicinal, firewood
Oleaceae	*Olea capensis*		Loliondo, mchio	Timber, fuelwood, poles, withies
Pedaliaceae	*Sesamum indicum*	Sesame	Ufuta	Edible seeds
Proteaceae	*Gravellia robusta*	Australian silky oak	Mkawilia	Timber, shade, fuelwood
Rosaceae	*Annona muricata*	Soursop fruit	Topetope	Edible fruit, fuelwood
	Eriobotrya japonica	loquat	Mstafeli	Edible fruit, fuelwood
	Malus sieversii	Wild apple	Apple pori	
	Prunus africana	Bitter almond	Mkondekonde	Fuelwood, windbreak, shade, timber
	Prunus persica	Peach	Sesu	Edible fruit, fuelwood
Rubiaceae	*Coffea arabica*	coffee	mkahawa	Coffee, fuelwood
	Pentas lanceolata			Weed, ornamental
Rutaceae	*Citrus limon*	Lemon	Mlimau, ndimu	Edible fruit, fuelwood
	Citrus sinensis	Sweet orange	Mchungwa	Edible fruit, fuelwood
	Citrus tangerina	Tangerine	Mchenza	Edible fruit, fuelwood
Sapotaceae	*Pouteria campechiana*	Canistel	Mzaituni	Edible fruits
Solanaceae	*Capsicum annum*	Red pepper	Mpilipili	Spices
	Capsicum frutescene	Bird chillies	Ngogwe	Edible fruit
	Lycopersicon esculentum	Tomato	Mnyanya	Edible fruit
	Solanum nigrum		Nafu	vegetable
verbenaceae	*Lantana camara*		Singarere	Hedge, grave marking, weed

Appendix 2: Dominant tree species found in agroforestry homegardens in highland agro-ecological zone

Sl. No	Scientific name	Trees in all sample farms No.	Number of farms where tree species is found	Percentage of occurrence of trees	Tree species basal area	Percent of sample farms with tree species
1	*Gravellia robusta*	438	35	28	21.74	87.5
2	*Persea americana*	284	37	18	14.08	92.5
3	*Albizia schimperiana*	227	34	14.5	23.98	85
4	*Mngoni*	163	7	10.5	5.10	17.5
5	*Rauvolvia caffra*	121	28	7.8	7.96	70
6	*Croton macrostachyus*	60	18	3.9	4.08	45
7	*Mangifera indica*	52	25	3.4	2.91	62.5
8	*Mwisi*	47	6	3	1.73	15
9	*Commiphora zimmermannii*	33	11	2.1	1.33	27.5
10	*Carica papaya*	18	8	1.2	0.43	20
11	*Cordia abyssinica*	18	6	1.2	1.18	15
12	*Prunus persica*	15	5	1	0.19	12.5
13	*Bridelia micrantha*	14	3	0.9	0.30	7.5
14	*Annona muricata*	13	6	0.8	0.13	12.5
15	*Olea capensis*	12	4	0.8	0.66	10
16	*Psidium guajava*	10	5	0.6	0.18	12.5
17	*Mfilomena*	8	4	0.5	0.33	10
18	*Ficus natalensis*	6	2	0.4	1.32	5
19	*Citrus sinensis*	3	2	0.2	0.03	5
20	*Citrus limon*	2	2	0.1	0.02	5
21	*Dalbergia melanoxylon*	2	1	0.1	0.04	2.5
22	*Ocotea Usambarensis*	2	1	0.1	0.09	2.5
23	*Citrus tangerina*	1	1	0.1	0.02	2.5
24	*Terminalia superba*	1	1	0.1	0.02	2.5
25	*Prunus africana*	1	1	0.1		2.5

Appendix 3: Dominant tree species found in agroforestry homegardens in midland agroecological zone

Sl. No	Scientific name	Trees in all sample farms No.	Number of farms where tree species is found	Percentage of occurrence of trees	Tree species basal area	Percent of sample farms with tree species
1	*Gravellia robusta*	230	30	15	13.590	75
2	*Persea americana*	182	36	11.8	13.309	90
3	*Mangifera indica*	176	35	11.5	13.826	87.5
4	*Cedrela odorata*	175	32	11.4	11.306	80
5	*Cordia abyssinica*	71	25	4.6	0.0181	62.5
6	*Carica papaya*	54	13	3.6	0.701	32.5
7	*Rauvolvia caffra*	49	19	3.3	3.234	47.5
8	*Commiphora zimmermannii*	49	17	3.2	0.975	42.5
9	*Albizia schimperiana*	45	16	2.9	9.973	40
10	*Artocarpus heterophyllus*	36	18	2.4	2.202	45
11	*Maragaritaria discoidea*	36	12	2.4	2.033	30
12	*Psidium guajava*	34	14	2.2	0.336	35
13	*Citrus sinensis*	31	14	2	0.334	35
14	*Croton macrostachyus*	30	15	2	1.849	37.5
15	*Sorindeia madagascarensis*	30	9	2	1.645	22.5
16	*Syzygium cumini*	27	16	1.8	2.195	40
17	*Ficus natalensis*	25	6	1.6	1.157	15
18	*Moringa oliefera*	25	3	1.6	0.176	7.5
19	*Markhamia platycalyx*	24	8	1.5	1.521	20
20	*Polyalthia longifolia*	23	5	1.5	0.381	12.5
21	*Senna siamea*	22	10	1.4	1.052	25
22	*Citrus limon*	15	8	1	0.185	20
23	*Milicia Excelsa*	15	9	1	2.257	22.5
24	*Mwisi*	13	4	0.9	0.342	10
25	*Annona muricata*	12	6	0.8	0.467	15
26	*Terminalia superba*	6	7	0.7	0.497	17.5
27	*Albizia gummifera*	9	5	0.6	0.661	12.5
28	*Punica granatum*	10	4	0.6	0.094	10
29	*Azadirachta indica*	9	6	0.6	0.317	15
30	*Terminalia catappa*	3	3	0.6	0.196	7.5
31	*Jacaranda acutifolio*	7	4	0.5	0.333	10
32	*Tamarindas indica*	6	5	0.5	0.537	12.5
33	*Cocos nusifera*	7	6	0.5	0.683	15
34	*Eriobotrya japonica*	7	3	0.4	0.188	7.5
35	*Malus sieversii*	6	2	0.4	0.068	5
36	*Prunus persica*	5	2	0.3	0.041	5
37	*Jatropha curcas*	4	2	0.3	0.058	5
38	*Newtonia buchannanii*	4	2	0.3	0.235	5
39	*Mpodo*	4	2	0.3	0.270	5
40	*Pouteria campechiana*	3	2	0.2	0.130	5
41	*Ficus exasperata*	1	1		0.132	

Appendix 4: Dominant tree species found in agroforestry homegardens in lowland agro-ecological zone

Sl. No	Scientific name	Trees in all sample farms No.	Number of farms where tree species is found	Percentage of occurrence of trees	Tree species basal area	Percent of sample farms with tree species
1	*Grevellea robusta*	386	31	27	14.88	77.5
2	*Mangifera indica*	139	31	9.7	9.60	77.5
3	*Senna siamea*	99	18	6.9	4.18	45
4	*Carica papaya*	74	19	5.2	1.27	47.5
5	*Persea americana*	73	22	5.1	3.67	55
6	*Citrus limon*	61	22	4.3	1.35	55
7	*Cocos nucifera*	58	15	4.1	4.65	37.5
8	*Rauvolvia caffra*	50	16	3.5	3.19	40
9	*Azadirachta indica*	49	20	3.4	1.60	50
10	*Polyalthia longifolia*	48	7	3.4	1.05	17.5
11	*Citrus sinensis*	42	14	2.9	0.88	35
12	*Albizia schimperiana*	40	7	2.8	1.41	17.5
13	*Krapus spp.*	39	6	2.7	0.95	15
14	*Cordia abyssinica*	31	6	2.2	0.96	15
15	*Leucaena leucocaphala*	29	8	2	0.58	20
16	*Psidium guajava*	26	9	1.8	0.39	22.5
17	*Eriobotrya japonica*	22	8	1.5	0.83	20
18	*Markhamia platycalyx*	16	2	1.1	0.35	2
19	*Citrus tangerina*	15	5	1.1	0.12	12.5
20	*Commiphora zimmermannii*	13	4	0.9	0.31	10
21	*Ficus capensis*	12	5	0.8	1.56	12.5
22	*Albizia gummifera*	10	4	0.7	0.64	10
23	*Jatropha curcas*	9	3	0.6	0.28	7.5
24	*Acacia totilis*	9	1	0.6	0.77	2.5
25	*Bridelia micrantha*	8	3	0.6	1.34	7.5
26	*Artocarpus heterophyllus*	8	4	0.6	0.41	10
27	*Moringa oliefera*	7	2	0.5	0.06	5
28	*Zyzygium guineense*	7	4	0.5	0.20	10
29	*Croton macrostachyus*	6	2	0.4	0.07	5
30	*Syzygium cumini*	5	2	0.4	0.53	5
30	*Tamarindas indica*	5	4	0.4	0.48	10
31	*Terminalia superba*	4	3	0.3	0.04	7.5
32	*Ficus natalensis*	4	2	0.3	0.25	5
33	*Annona muricata*	3	2	0.2	0.05	5
34	*Milicia Excelsa*	3	2	0.2	0.49	5
35	*Terminalia catappa*	8	3	0.2	0.30	7.5
36	*Acacia xanpholea*	3	2	0.2	0.23	5
37	*Adansonia digitata*	3	2	0.2	0.11	5
38	*Jacaranda acutifolio*	2	2	0.1	0.31	5
39	*Anacardium occidentale*	2	2	0.1	0.15	5
40	*Senna singueana*	2	1	0.1	0.06	2.5
41	*Maragaritaria discoidea*	1	1	0.1	0.08	2.5
42	*Pouteria campechiana*	1	1	0.1	0.01	2.5

Appendix 5: Livestock population of surveyed households in Agroforestry homegardens of Moshi Rural District

Agroecological Zone	Livestock population*					
	Cattle	Goat	Chicken	Sheep	Pig	Duck
Highland	66 (42)	45 (24.6)	329 (35.3)	22 (30.1)	(0)	9 (28.1)
Midland	39 (24.8)	40 (21.9)	303 (32.5)	10 (13.7)	37 (48.7)	13 (40.6)
Lowland	52 (33.1)	98 (53.6)	299 (32.1)	41 (56.2)	39 (51.3)	10 (31.3)
Total	157 (100)	183 (100)	931 (100)	73 (100)	76 (100)	32 (100)

*Figures in parenthesis are percentages.

Appendix 6: Questionnaire used to collect data in Moshi Rural District

Core Var. No.	Variable label	Variable codes and values
DIST	District....	
VILL	Full name of village...	
CONTACT	Mobile number	
RESP	Respondent	1. Household head, 2. Spouse of household head 3. Grown up child, 4. Relative 5. Parent of household head, 6. Other ( )
MARITAL	Marital status of household head	1.Married 2.Single 3.Divorced 4.Separated 5.Widowed
SEX	Sex of head of household	1. Male 2. Female
AGE	Age group (years)	1. 15-24 2. 25-34 3. 35-44 4. 45-54 5. 55 plus
EDUC	Educational level of household head	1.No Formal Education 2. Primary 3. Secondary 4. Diploma 5. Degree and above

Total area of the land: ___ Acres Number of household members: _____

A. To identify the agroforestry systems and technologies of agroforestry homegardens practiced

1. What components do you have in your homegarden? Circle them.

1. Crops 2. Trees 3. Grasses 4. Animals 5. Bee hives 6. pond for fish 7. Others (mention them) .....

2. How have the components present in the homegarden combined and why?

.....

.....

B. To assess and quantify the composition, structure and diversity of homegardens

3.Name crops that are found in your homegarden

.....

.....

4. Name the trees that are found in your homegarden

.....

.....

5. Name the animals that are found in your homegarden

.....

.....

6. Name other things that are found in your homegarden

.....

.....

Local Name	Botanic name	Quantity	DBH (for trees)	Height (m)

4. To determine changes in composition over time

7. Mention different crops, trees, animals and other components that were found in your farm in indicated time periods in the table.

Time period	Crops	Trees	Animals	Other components
1990's				
2000's				
2010's				
Currently				

8. Reasons for adoption of new crops or trees in any time period.
9. Reasons for stopping planting crops and trees in a certain time period
10. Reasons for adoption of animals in different time periods
11. Reasons for stopping keeping the animals that was available in the previous list
12. Reasons for adoption of other components in different time periods
13. Reasons for stopping keeping other components in different time periods.

5. To determine the implications of the changes to agroforestry homegardens on the livelihoods of the local communities

14. What is the average yield per year of each component found in the homegarden? (Fill in the table)

Table. For determination of the implications of the changes in agroforestry homegarden composition on related community livelihoods

Component	Quantity	Average yield/ year	Amount used in home	Amount for selling	Selling price T.sh

15. How do you regard the current productivity of AF/ homegardens as compared to the past?

(i) Very good (ii) Good (iii) Satisfactory (iv) Poor (v) Don't know

What are the criteria that helped you to make such judgment/conclusion?

.....

.....

16.What is the trend of productivity of your homegarden for the past 10 years?

1) Decreasing 2)Increase 3)Constant 4)Not known

17.What do you think are the possible reasons for an answer given above

.....

.....

17. Main usage of the products from the agroforestry homegarden

(1)Household consumption

Mention the components:

.....

.....

(2)Selling in the market

Mention the components:

.....

.....

Other uses

Mention the uses and components:

.....

.....

18. Do the products from the homegarden enough to sustain the needs of the family all the year?

1. Yes (go to question 19) 2. No (go to question 20)

19. If the answer is yes, is there any excess left after the needs of the family has been met?

1. Yes (go to question 21) 2. No

20. Why and where does the family got the income to sustain its needs apart from agroforestry homegarden?

.....

.....

21. What is the family doing with the excess products from the homegardens

1. Store them for future use 2. Sell them to get more income (go to question 22)

3. Other uses, mention them

.....

.....

22. Is there market for the products from the farm?

0. No 1. Yes

23. Where do you sell your products?

0. Do not sell 1. Neighbour 2. Local market/trade store

3. Secondary market

4. Tertiary market 5. Marketing coop 6. Farmer association 7.Large-scale farm

8. Traders at farm 9.Contract partner

24. Which one of the products sold is most profitable?

0.None of the product was profitable 1.1st most important product.....

2nd most important product ..... 3rd most important product .....

25. In your view, how has the overall market access for these products changed during the last five years?

.....

.....

26. Are there other forms of selling these products?

0. NO 1. YES

27. Are the products from homegarden sufficient for:

Food availability. 0. Yes 1. No

28. Energy especially wood 0. Yes 1. No

29. Wealth for buying assets 0. Yes 1. No

Name of the Interviewer: ..... Date..... Signature.....