# THE CONTRIBUTION OF AGROFORESTRY TO HOUSEHOLD FOOD SECURITY AND INCOME GENERATION OF THE LOCAL COMMUNITIES IN ARUMERU DISTRICT, ARUSHA, TANZANIA

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A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN MANAGEMENT OF NATURAL RESOURCES FOR SUSTAINABLE AGRICULTURE OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.



2013

## ABSTRACT

The present study was conducted in Arumeru District, Arusha Region, with the objective of assessing the contribution of agroforestry to household food security and income generation of the local communities. The methods involved stratification of the district into three agro-ecological zones, randomly selecting two wards per each agro-ecological zone, one village per each ward and twenty households from each village to form a total of six wards, six villages and 120 households. Data collection was done through reconnaissance, social and field surveys. Results indicated that 71% and 59% of the households in Arumeru District depend on agroforestry as their main source of food and income livelihood respectively. Agrosilvopastoral system constituted 78% of all agroforestry practiced in the district and 33% of the agroforestry practices being of homegardens technology. The results indicated further that agroforestry contributed 89% to food security and 84% to income generation of the households of the local communities. It is concluded that besides being the most important source of peoples' food security and income generation in the district, agroforestry has the advantages of increasing, multiplying and diversifying the per unit resources management products while holding the capacity to spread the systems outputs over different seasons of the year, which are significant attributes for assured food, income and nutrition sustainability. The availability of good road network and soil fertility were the most important enhancing factors for agroforestry adoption, drought and lack of knowledge are the most significant limiting factors while provision of water for irrigation and extension services were required interventions in improving the performance of agroforestry in the district. The study recommends for more vigorous promotion of agroforestry practices in the district by paying more attention to the indicated factors influencing and required interventions for its enhanced adoption and contribution to food security and income generation of the communities of Arumeru District.

## DECLARATION

**I, PAMELA EZROM KESSY**, do hereby declare to the Senate of Sokoine University of Agriculture that, this dissertation is a result of my own original work done within the period of registration and that it has not been submitted nor being concurrently submitted in any other institution.

10/10/2013

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Date

The above declaration is confirmed

11/10/2013

Prof. L. L. L. Lulandala

(Supervisor)

Date

## COPYRIGHT

## ACKNOWLEDGEMENT

During my course of study I was privileged to work with many dedicated personalities of whom I hereby acknowledge them for their various roles towards the success of this study. I would like to sincerely recognize my supervisor Prof. L. L. L. Lulandala for his availability, persistent follow up, critically reading my drafts and providing insightful inputs that eventually shaped and improved the quality of this work.

I wish to express my appreciation to my sponsor Belgium Technical Co-operation (BTC) for funding my Master study programme. I express appreciation to all 2010-2012 classmates' and lecturers of MNRSA course with whom I shared their experiences and company.

I greatly appreciate my parents, the late Mr. Ezrom Kessy and Mrs. Grace-Mary Kessy for instilling in me the sense of academic pursuits and my brother Godbless, Hillary, Alex and sister Suzan and Maurine, for their prayers and continued encouragement towards achieving my academic goals. In a special way, I recognize my mother, who has been a source of inspiration through her inspiring leadership throughout my life.

In a very special way, I give my heartfelt appreciation to my dear husband, Erasto Obel Malila, for his continuous support emotionally and academically during the course of this study. He thoroughly read and commented on drafts, offering insightful inputs; similarly he was available to ensure that the children lacked nothing for the sake of my academic endeavors. He has been the foundation of my academic success.

Above all I thank the Almight God for the good health, the will to forge ahead and stability of mind amidst all other responsibilities that awaited my attention. Because of His love, I have made it this far.

## DEDICATION

I dedicate this dissertation and all its fruits to the Almighty God, my beloved husband Mr. Erasto Obel Malila and our blessed children, Elizabeth, Ebenezer and Elieshi.

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## LIST OF ABBREVIATIONS AND SYMBOLS

| | |
|---|---|
| a.s.l | Above sea level |
| ANOVA | Analysis of Variance |
| BC | Before Christ |
| BCIS | Business Case and Intervention Summary |
| CRBD | Completely Randomize Block Design |
| DADPs | District Agricultural Development Programs |
| DALDO | District Agriculture and Livestock Development Officer |
| | Deficiency |
| FAO | Food and Agriculture Organization |
| FTI | Forestry Training Institute |
| GDP | Gross Domestic Product |
| HIV/AIDS | Human Immunodeficiency Virus/Acquired Human Immune |
| ICRAF | International Centre for Research in Agroforestry |
| ILO | International Labour Organization |
| JICA | Japan International Co-operation Agency |
| LSD | Least Significant Difference |
| MNRSA | Management of Natural Resources for Sustainable Agriculture |
| MNRT | Ministry of Natural Resources and Tourism |
| NGOs | Non Government Organizations |
| RECODA | Research Community and Organizational Development |
| SAS | Statistical Analysis System |
| SCAPA | Soil Conservation and Agroforestry Programme in Arusha |
| SUA | Sokoine University of Agriculture |
| SWF | State of the World's Forests |

| | |
|---|---|
| TAFORI | Tanzania Forestry Research Institute |
| TEP | Tanzania Economy Profile |
| TFNC | Tanzania Food and Nuntrition Centre |
| URT | United Republic of Tanzania |
| USA | United States of America |
| USAID | United States Agency for International Development |
| VEO | Village Executive Officer |
| VICOBA | Village Community Bank |
| WAC | World Agroforestry Center |

# CHAPTER ONE

## 1.0 INTRODUCTION

### 1.1 Background Information

Agroforestry is an integrated approach to address food insecurity and income by deliberately combining trees/shrubs into crop and/or livestock production systems instead of relying on expensive inputs of modern agricultural technologies (Nair, 1993). Agroforestry researchers have come up with various technologies which yield improved food security and income livelihoods (ICRAF, 2009). Agroforestry is among the supporting practices, which are purposely introduced to restore land productivity, improve the ecological and living conditions of the rural families (Oyebede *et al.*, 2010). Under continuous cultivation, agroforestry increases food production, ensures streams of income and maintains the fragile and limited land resources (Ogundari and Ojo, 2007; Oyebede *et al.*, 2010). This practice has been used successfully for food production and income generation in the highlands where the population density is high (Nair, 1993). In the areas with land fragmentation agroforestry has promoted sustainable food security, income generation, employment growth and export enhancement (Regmi, 2003). As a result, it contributes to the improvement of livelihoods of the communities which largely depend on agriculture and/or livestock keeping. WAC (2009) reported that in the year 2004, the National Agroforestry Strategy (NAS) envisioned four million rural households adopting and benefiting from agroforestry practices by the year 2025. Its goal was that by the year 2020, agroforestry would have been adopted and contributing in improving the livelihoods of 60% of the country's resource poor households. Moreover, this practice is regarded as the oldest land use system with the aim of solving problems of land shortage, food insecurity and poverty (Ogundari and Ojo, 2007; Quandt, 2010). In Tanzania, traditional agroforestry has been practiced for more than 3 000 years (O'Kting'ati, 1985; Rugalema,

1992). Technologies such as the Chagga homegardens in the northern highlands of the country (WAC, 2009) and those of Kagera (Rugalema, 1992) are where trees, agricultural crops and livestock are combined on the same piece of land simultaneously or sequentially (Fernandes *et al.*, 1985). For example, around the Lake Victoria zone in the northwestern part of the country, are the Mara Region homegardens known as Obohochere, on the southern part of the lake are the Sukuma Silvopastoral technologies called 'Ngitiri' (WAC, 2009), on the western part of the lake are the Kibanja technologies of the Haya tribe (Maruo, 2002). The type of agroforestry systems and technologies practiced depend mainly on the potential economic activities of the involved communities and their needs (Lulandala, 2010).

According to the FAO World Food Summit (1996), "food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life." Sources of household food security and income generation include agroforestry, livestock, agriculture, forestry, business and employment. Although agriculture is the major base of employment and livelihood of about 80% of the Tanzanian population, still 20.4% are food poor while 38% of them live below the basic poverty line (Myaka *et al.*, 2003). Findings by USAID (2009), reported that more than 1.5 million people are food insecure in 63 districts in 15 regions of Tanzania. This has been contributed by a drop of production in the agricultural sector due to land degradation, soil erosion and drought. Also, inadequate access to the means of production such as improved seeds, fertilizer inputs, appropriate technologies, land and chemicals to control diseases and pests and farm credits to farmers lead to lower income generation and food deficits as a result of poor agricultural productivity (Kaukab and Chakravartii, 2011).

Therefore, agroforestry combines agriculture, forestry and various other components to create more diverse, productive, profitable, healthy and sustainable resource use systems (Odoul *et al.*, 2006; Oke and Odebiyi, 2007; Kellimore, 2010; Oyebede *et al.*, 2010). It has already shown great promise with respect to enhanced productivity and nutrient accumulation in many geographical regions around the world (Chirwa *et al.*, 2007). If agroforestry practices are vigorously promoted, they will effectively solve the problems of food insecurity and income generation in rural areas (Garrity, 2004; Parwada *et al.*, 2010), while continuous on-farm tree growing by farmers increases the value of the on farm assets to be inherited (Irshad *et al.*, 2011). Adoption of agroforestry as a land management strategy is therefore highly needed for smallholder farmers due to small land holdings, high cost of production inputs, poor market structures, fodder needs and fuelwood requirements (Mukadasi and Maxwell, 2008). For example, 92% of the total energy consumed in Tanzania, is wood based, largely firewood collected by households to meet cooking, brick burning and heating livelihood needs (JICA, 2006).

### 1.2 Problem Statement and Justification of the study

Agroforestry is rapidly becoming a significant resource management system with a potential of most adequately meeting the farmers' basic needs due to its ability of sustaining food supply and income generation via its components diversity (Lulandala, 2010; Oyebede *et al.*, 2010; Quandt, 2010). A world increase in population, is approximately nine billion people by the year 2050 (FAO, 2009). The highest increase is expected to be in the underdeveloped countries. Thus, an increase in food production is required (Neufeldt *et al.*, 2009). Even with a global expansion of food supply by about 70% necessary to feed the world's population in the year 2050, almost 400 million people will still lack access to adequate food (FAO, 2009). Verchot *et al.* (2007) reported agroforestry practices to be a means of diversifying production and increasing food

security and income for the small scale agricultural producers. About 1.2 billion people or 20% of the world's population, depends on agroforestry products and services for their livelihoods (ICRAF, 2006). Observations made by the WAC (2009) suggest that these numbers may, in fact, be lower, and that nearly half of the world's farmlands have, at least 10% tree cover, spanning over more than 10 million square kilometers in total. Sileshi *et al.* (2007) and Kebebew and Urgessa (2011) have pointed out that, the contributions of agroforestry to household food security and income generation to some extent have not been appreciated at the national level in many countries. WAC (2009) reported that the current policies of Tanzania do not take advantage of these promising technologies of agroforestry. Researchers have pinpointed the potential of agroforestry interventions to households livelihood support in Arumeru District. Makawia (2003) reported on human nutrition by the use of agroforestry products. Kajembe *et al.* (2005) observed on the indigenous-based interventions on land conservation require minimal labour and capital to have been highly adopted by farmers because have eased farm operations and contributed towards improved soil fertility, increased crop yield and income generation. Mwakatobe (2001) reported homegarden on beekeeping activities gives local people and the Government economic incentive for livelihoods. Local communities of Arumeru District rich in indigenous knowledge on beekeeping activities, incorporating beekeeping as one of the important components of homegarden and the bee-products providing a significant contribution to the food security and economy of the homegarden households. But information on empirical contribution of agroforestry to household food security and income generation, particularly on household food availability as one of the three pillars of food security in Arumeru District, is lacking.

Therefore, the purpose of this study was to determine the extent of agroforestry contribution to the household food security and income generation in Arumeru District.

Besides providing documentary information, the results of the present study will form a significant basis for the farmers, government and NGOs involved in agroforestry extension in Arumeru District, in planning for enhanced food security and income livelihoods of the local communities.

## 1.3 Objectives

### 1.3.1 Overall objective

The overall objective of this study was to assess the contribution of agroforestry to household food security and income generation of the local communities in Arumeru District, Arusha, Tanzania.

### 1.3.2 Specific objectives

The specific objectives of this study were to:

i. Identify the various sources of household food security and income generation of the local communities.
ii. Determine different agroforestry systems and technologies in use in the district and their levels of adoption.
iii. Establish the extent of agroforestry contribution to household food security and income generation of the local communities in the district.
iv. Identify factors influencing the adoption of agroforestry and measures required for improvement.

# CHAPTER TWO

## 2.0 LITERATURE REVIEW

### 2.1 The Various Sources of Household Food Security and Income Generation

#### 2.1.1 Food security

Food security has different meanings to different people (Ndaeyo, 2007). In the 1970s food security was mostly considered in terms of national and global food supplies. In the mid 1980s it became clear that adequate food availability at the national level did not automatically translate into food security at the individual and household levels (Frankenberger and McCaston, 1998). That is to say, at household level, food security concerns elements that are food supply and the access or ability of a household to acquire food (Kaukab and Chakravartii, 2011; Kebebew and Urgessa, 2011).

The FAO World Food Summit (1996) reported that, food security is built on three pillars: Food availability, access and appropriate use based on knowledge of basic nutrition, care and sanitation. To obtain their food, households typically grow it and consume from their own stocks; purchase it in the marketplace; receive it as a transfer from relatives, members of the community, the government or foreign donors or gather it in the wild (Ndaeyo, 2007; Kebebew and Urgessa, 2011). Households which rely on the market purchases as their important sources of food, cash incomes are likely to be more important for their food security status (Monde *et al.*, 2008). For example 88% of the households in Jimma, Southwestern Ethiopia, attain their food security through purchasing from local markets (Kebebew and Urgessa, 2011). Similarly, livestock are likely to be more important as food and income sources for the agro-pastoralist groups than for farmers (Riely *et al.*, 1999). The most dependable way to obtain food is through own production, as food aid is transitory (not certain) while purchases are influenced by the purchasing power of

individuals or a nation, which are also, affected by inflation (Ndaeyo, 2007). A household is said to be food insecure when it fails to have sufficient quantities of food on a consistent basis, sufficient resources to obtain foods and appropriate knowledge based on the use of basic nutritious foods available (World Food Summit, 1996). Findings in Kenya by Musotsi *et al.* (2008) reported seasonal hunger during which household food needs were not adequately met. In Zambia, Kalaba *et al.* (2009) revealed that over 90% of rural households experienced regular hunger periods. Similar findings have been reported in Tanzania by Kajembe *et al.* (2000) who suggested that household food insecurity was widespread and chronic in some areas of Tanzania, since there was a certain degree of food deficit at one time or another during the year. This implies that most households suffer from lack of income and food insecurity (Kalaba *et al.*, 2010).

Causes of food insecurity have been identified as being crop failures, storage deficiencies and sale of food in higher proportions than food security would require (TFNC, 1992). It had been reported that in India, 35% of the produce was used for self consumption and 65% was sold in the local markets (Tynsong and Tiwari, 2010). A leading determinant of food insecurity is low levels of per capita food production. But the primary constraints to improved food production in the regions are a combination of low and erratic rainfall, high population densities, deforestation and consequently accelerated deterioration of soil quality and crop yields (Monde *et al.*, 2008). Buyinza and Wambere (2008) reported that, in Uganda most soils were in the final stage of weathering. Poor market infrastructure and unfavorable policy environment lead to high and variable prices for inputs and low producer prices have been reported by Kaukab and Chakravartii, (2011). Inadequate purchasing power among the rural poor and consumer purchasing power have been declining over years in Tanzania. The hardest hits are the low wage earners and the rural poor who usually face food deficits and as such have to buy food (Kajembe *et al.*, 2000).

### 2.1.2 Income generation

Agroforestry provides useful and marketable products as it diversifies the timing of production so that farmers do not receive their entire year's income at one time (Oyebede *et al.*, 2010). The observation made by Mtuya (2006) indicates that apart from using the crops for food in the household, farmers sell their crops to get money for other uses such as health care and educational expenses. Sales of livestock and livestock products, for example, provide farmers with cash to purchase household necessities and farm inputs (Mphuru, 1991). For instance about 0.4% of the households in Tanzania keep livestock only and 40% approximately 4 mill agricultural households are involved in crop and livestock production (URT, 2001). Kazungu and Magigi (2012) reported a positive relationship between household income and livelihood strategies. Kebebew and Urgessa (2011) reported poor farmers to be practicing agroforestry to mitigate their socio-economic needs and being their major source of income, providing nearly half of their total income. Similarly, in many semi-arid areas, cattle were reported to be used as a safety net for food security and income generation (Wiskerke, 2008). Kajembe *et al.* (2000) suggested that a household or individual who spends over 70% of ones total income on food is said to be poor and food insecure. Such an individual will hardly meet other life's essential needs such as education, health care, housing, etc., with the remaining 30% of that income.

### 2.1.3 Sources of household food security and income generation

In many countries south of Sahara, the population growth rate ranges from 1.4% to 2.5% while the rate of food production is 1.2% per year, this implies that, the amount of food produced is not enough to feed the population (FAO, 1991). Different farming systems are used for the purpose of food security and income generation. Therefore, agroforestry offers a potential solution to the problem of declining rural agricultural production, thus

making an important source of food security and income generation to the households (Zeleke, 2009; OlajideTaiwo *et al.*, 2010; Opala, 2011). Studies including those of Ndaeyo (2007), Oyebede *et al.* (2010) and Quandt (2010), suggest that agroforestry practices improve household food security and income generation. Findings from Bangladesh revealed that 70% of the farmers were the main users and beneficiaries of agroforestry due to the significant amount of income attained (Rahman *et al.*, 2008). In Tanzania, different products are grown in homegardens. These include a range of agricultural products which are both exotic and local varieties of vegetables such as tomatoes, cabbage, onions, amaranthus, okra, carrots, sweet peppers, egg-plant and green peas (URT, 2009).

Households may sell a variety of products produced in the homegardens, including fruits, vegetables, various animal and insect products and other valuable materials such as bamboos and wood used for construction or fuel. More than 2 500 women from 50 women's groups are employed in fruit processing enterprises in western Tanzania (WAC, 2009). They may, therefore, use the income to buy food.

The business plays an important role in socio-economic development worldwide. In developing countries like Tanzania, it is estimated that one third of the country's GDP originates from the micro, small and medium social enterprise sectors (Mbura, 2007) with about 1.7 million businesses engaging about 3 million people (URT, 1991). More than 80% of the workforces in rural and urban populations are in these sectors (ILO, 2003) as means to obtain income and in turn food security.

Swift (1988) suggested that, the agricultural production system is the one in which more than 50% of household gross revenue comes from farming, and 10% to 50% from livestock keeping. Agriculture is of major importance to Tanzania and its role is crucial to

the livelihood (Kashulinza *et al.*, 2002; DADPs, 2012). Higher agricultural productivity means higher food supplies and lower food prices for the consumers and increased farmer/producer incomes which affect livelihood choices. The sector is of importance due to the percentages of the labour population it employs (Kaukab and Chakravartii, 2011). TEP (2011) reported about 41.6% of the country's gross domestic product (GDP), 80% employment and 85% of its export earnings. In spite of its positive contribution, the topographic and climatic conditions limit cultivated crops (Kaukab and Chakravartii, 2011; TEP, 2011). Despite the efforts made over the years to develop agriculture, the problems of hunger, famine, and malnutrition and land degradation still remain and present the threat to the survival of the nation (World Bank, 1993). During the period between 2001/02 to 2008/09, agricultural productivity declined for several key food crops (Kaukab and Chakravartii, 2011).

Although, Tanzania is positively endowed with the abundance of land which could be used for agricultural production, the more determinant factors are the quality of such land and availability of other physical inputs such as water and climatic factors (Kaukab and Chakravartii, 2011). Lack of organic matter in soils, shortage of rains, low purchasing power for agricultural inputs due to poverty and reduced manpower due to HIV/AIDS contribute highly to low food production (Mtuya, 2006). Failure to promote trade on agricultural products and export adopted on certain agricultural commodities which affect smallholder farmers due to falling prices, and force them to abandon production practices or, sometimes, shift to other occupational practices (Sood, 2006; Kaukab and Chakravartii, 2011), also, affects agricultural production. Other factors include market failures and the inability experienced by farmers to benefit from cheap inputs such as fertilizers. Subsidy policies and distribution systems, if implemented efficiently can be used effectively in the provision of such inputs to rural farmers, thus making their access easier and cheaper for

them. These policies concerning subsidies, however, need to be adopted with some caution, as they can prove to be expensive, inefficient and difficult to remove when ineffective (Kaukab and Chakravartii, 2011). Land entitlement and tenureship create incentives for farmers to invest in the land which directly affect agricultural productivity.

In tropical Africa, forests cover about 520 million hectares (FAO, 1997). Tanzania has about 38.5 million hectares of forests and woodlands representing 40% of the country's total land area (URT, 1998). In arid and semi arid areas, most of the land is dominated by scattered thickets and bushlands except in small areas which are permanent water springs or seasonal rivers in which one can observe small forests relatively dense and evergreen normally with approximate sizes between 0.5 and 5 hectares, surrounding the water sources and along river courses (Rurai, 2007). Throughout the tropics, there are indigenous tree species that produce locally important foods and other non-timber forest products, most of which are used as food or energy sources and generate income to households (Akinnifesi *et al.*, 2006; Mtuya, 2006; Hill, 2007; Sileshi *et al.*, 2008; Oyebede *et al.*, 2010). It is being realized that forestry contributes to improving the environment, enriching the natural resources, and creating income opportunities for previously disadvantaged communities. It is an important component of the range of activities needed in every rural community to create employment. But forestry was failed in South Africa due to wrong understanding of people's needs and fuel wood crisis (Ham and Theron, 2010).

Employment refers to any activity, occupation, work performed by people for remuneration, in cash or kind, profit, social or family gain, or by force, including under a contract of hire, written or oral, expressed or implied and regardless of whether the activity is performed in a self-directed, part time, full time or casual basis (FAO, 2011).

Full and productive employment and decent work for all are key to poverty reduction and increased food security through income generation (FAO, 2012). Employment for income generation is an explicit element of the FAO's strategic approach to improved food security and income generation (FAO, 2010a). The food security of most rural households in South Africa is primarily based on purchasing food by the income derived from employment or claiming from the state (Monde *et al.*, 2008). Poor people may spend as much as 70% of their income on food (FAO, 2010b).

Animals such as goats, pigs, poultry and products that are derived from them including milk, cheese, eggs etc. are other sources of food. These products are either consumed in the households or sold in marketplaces. Swift (1988) suggested that, livestock production systems are those in which 50% or more of households gross revenue (that is the total value of marketed production plus the estimated value of subsistence production consumed within the households) come from livestock or livestock-related activities or where more than 15% of household food energy consumption consists of milk or milk products produced by the households. Bonifasi (2004) reported that, by using the income obtained from milk production, farmers afforded to buy suitable hybrid cattle and thus higher levels of production for food security and income generation.

## 2.2 Agroforestry Systems and Technologies in use

### 2.2.1 Agroforestry systems

Agroforestry is an integration of resource management approach which deliberately combines woody perennials with herbaceous crops (maize, beans, bananas) and/or animals (cattle, goats, sheep, chicken), aquatic life-forms (fish, shrimps, crocodiles, crabs) and insects (bees, grasshoppers, locusts, butterfly caterpillars) on the same resource management unit (Lulandala, 2012). It is a dynamic, ecologically based, natural resources

management system that through the integration of trees in the farms and rangelands diversifies and sustains production for increased social, economic and environmental benefits (Irshad *et al.*, 2011). The impact of Agroforestry on sustainability, arises primarily through the trees and their regenerative effect on soil fertility, shelter and fodder they provide for livestock and the range of tree products directly useful to people. Oyebede *et al.* (2010) reported agroforestry to optimize the positive outcomes of more diversified and sustainable production systems from the limited resources than other systems of resources use. The three oldest and most widely known categories of agroforestry are the agrosilvicultural, silvopastoral and agrosilvopastoral systems (Nair, 1993).

Agrosilvicultural system makes a combination of agricultural crops and woody perennials of shrubs, trees and vines. The system is used to produce agricultural crops and tree based products. It has high potential in areas where agricultural crop production is the dominant economic activity of the involved communities (Oyebede *et al.*, 2010; Lulandala, 2010). The silvopastoral system involves deliberate integration of trees/shrubs into pastures or grasslands to improve their products (meat, milk, hides and skins, animal dung) and make the various tree based products available to the community (Oyebede *et al.*, 2010). It improves the nutritional and healthy status of the community through fruit, vegetable, medicinal and various tree/shrub based products. Animals are the main characters of this production system.

Agrosilvopastoral system is an integration of agrosilvicultural and silvopastoral systems. It includes agricultural crops, trees and animals in the same unit of the land (Odoul *et al.*, 2006; Oyebede *et al.*, 2010). This system is of value in areas where crop production and animal husbandry go hand in hand as equally important economic activities of the

practicing communities (Lulandala, 2010). This association of trees, agricultural crops and animals in the same resource management system is an ancient practice throughout the world, and probably dates back as far as 7000 BC, in the form of shifting cultivation (ICRAF, 2006).

Lulandala (2012), reported of other types of agroforestry systems that include an agroaposilvicultural system which comprises of the woody perennials (trees or shrubs, coconuts, bamboos), herbaceous crops (maize, beans, banana) and insects (bees, grasshoppers, locusts, butterfly caterpillars). Aquosilvicultural system which includes woody perennials (trees or shrubs, coconuts, bamboos), and aquatic life-forms (fish, shrimps, crocodiles, crabs); agroaquosilvicultural system which includes woody perennials (trees or shrubs, coconuts, bamboos etc), herbaceous crops (maize, beans, banana) and aquatic life-forms (fish, shrimps, crocodiles, crabs), aposilvopastoral system which includes woody perennials (trees or shrubs, coconuts, bamboos), animals (cattle, goats, sheep, chicken) and insects (bees, grasshoppers, locusts, butterfly caterpillars), aquosilvopastoral system which includes the woody perennials (trees or shrubs, coconuts, bamboos), animals (cattle, goats, sheep, chicken) and aquatic life-forms (fish, shrimps, crocodiles, crabs).

Apoaquosilvicultural system include woody perennials (trees or shrubs, coconuts, bamboos), insects (bees, grasshoppers, locusts, butterfly caterpillars), and aquatic life-forms (fish, shrimps, crocodiles, crabs), apoaquosilvopastoral system which includes woody perennials (trees or shrubs, coconuts, bamboos), animals (cattle, goats, sheep, chicken), insects (bees, grasshoppers, locusts, butterfly caterpillars), and aquatic life-forms (fish, shrimps, crocodiles, crabs), agroapoaquosilvicultural system which includes the woody perennials (trees or shrubs, coconuts, bamboos), herbaceous crops (maize, beans,

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### 2.2.2 Agroforestry technologies

The term agroforestry technologies are used in all agroforestry systems to describe the various arrangements of the agroforestry components of systems on the resource management units (Lulandala, 2010). Agroforestry technologies focus on the role of trees on farms and landscapes to meet the structural and ecological needs (Garrity, 2004). These include homegardens, live fences, boundary planting, alley farming, taungya, shelterbelt and windbreaks (Akinnifesi *et al.,* 2008; Oyebede *et al.,* 2010).

#### Homegardens

Homegardens technologies refer to the deliberate management of multipurpose trees or shrubs in an intimate association with the annual (herbaceous) crops and/or livestock, insects, aquatic life forms within or near the compounds of household (Oduol *et al,* 2006; Mwakatobe, 2001). Such technologies have been reported where populations have reached high peaks due to high productivity (Nair, 1994), such as in the Kenya highlands, most of Rwanda, on the slopes of Mount Kilimanjaro, Mbeya and Bukoba Region in Tanzania (Rugalema, 1992; Maruo, 2002; WAC, 2009). The major feature of homegardens is a high diversity of components, sophisticated structures including various patterns and with integration of stall feeding of livestock (Akinnifesi *et al.,* 2010; Zeleke, 2009). Homegardens were reported to be basic production units, centers of social cultural well being of farm families and as units of survival for local population (O'kting'ati and

Mongi, 1996). It is important for poor households to overcome adversity and meet the basic needs (Maroyi, 2009; Tynsong and Tiwari, 2010). Homegardens have been used to sustain rural life by providing enough food, incomes and sustaining production with minimum inputs (Mwakatobe. 2001). The magnitude and rate of production of homegardens depend on their range of the components. The choice of species is determined by the climatic conditions, social economic factors, dietary habits and market demands (Munishi *et al.*, 2004). However, the vast majority of homegardens are for subsistence production. Yields are generally low but this is more than compensated for by the diversity and nutritious nature of the products (Musotsi *et al.*, 2008). This continuous production facilitates the harvesting of the required products when they are needed for consumption and, thereby, considerably reducing post harvest losses. In homegardens are found various products example yams, beans, maize, fruits, vegetables, and other various animal products are available for the whole year. Thus, homegardens are economically efficient, ecologically sound, and biologically sustainable (Nair, 1993).

**Mixed intercropping planting**

This practice is common in the highlands where shade trees are grown with plantation crops. Plantation crops traditionally grown are like *Elettaria sp.* (cardamom), coffee, tea and cacao. The crops are growing as a farmer's source of cash. Trees like *Gliricidia sepium* and *Gravillea robusta* are commonly preferred as shade trees (Quandt, 2010). Among the ecological and economic roles of these trees include soil fertility improvement, thus reducing the need for industrial fertilizers which are increasingly being more costly and their soil acidification side effects. It improves the micro-climate conditions and provides wood products for various uses such fuel wood, timber, poles and fodder for animals. Mgeni (2008) reported of mixed intercropping as having high potential in maintaining soil fertility with high quality fodder and hence preferred by farmers. By

providing nutrients to crops, these practices can potentially help farmers improve their soils and incomes, thereby improving food security (Kiptot and Franzel, 2011).

**Livefences and or boundary planting**

This is a simple but effective practice particularly for small farmers. It consists of planting trees along the boundaries of the fields and farms or along the avenues of footpaths, roads and canals. It is also called four sided forestry with the object of gaining production from trees, while having no adverse effects on adjacent crops and possibly a beneficial effect through fertilization by the trees or their leaf litter, protection from wind or aiding soil conservation i.e. watershed protection. Parwada *et al.* (2010) reported that the adoption of livefence was high because of the need to protect fields from the stray animals during the dry season.

**Fodder bank**

Fodder bank involves growing, harvesting and preservation of browse of nutritious protein rich leguminous tree leaves during the wet season and using them as a protein supplement for ruminant animals during the dry season (Sileshi *et al.*, 2007; Parwada *et al.*, 2010). Fodder shrubs are grown along boundaries and pathways or in lines to form terraces, thus reducing soil erosion and providing firewood. They establish in nine to twelve months and can subsequently be cut periodically and fed to cows and goats (Kiptot and Franzel, 2011). Fodders can be used for controlling browsing or feeding to animals in an enclosure in a cut and carry fashion (Sileshi *et al.*, 2007). A study in East Africa showed that 500 shrub species such as *Calliandra calothyrsus* are sufficient to feed one dairy cow for one year when used as a substitute for dairy concentrate (Ajayi *et al.*, 2006; Franzel and Wambugu, 2007). Although commercial feed concentrates are available, smallholder farmers consider them expensive and many cannot afford them. Over 200 000 farmers in East and Southern

Africa have established fodder banks (Franzel and Wambugu, 2007). The use of fodder shrubs is beneficial to women in many ways. The income obtained is normally used to pay school fees, general household improvement, fuelwood, fodder and improved food and nutrition for the family.

**Rotational woodlots**

The rotational woodlot system involves intercropping of annual crops for two to three years in the early stage of tree growth and again after the harvest of trees for two to three years later, keeping the stumps very low depending on the tree species (Otsyina *et al.*, 1996). When yields decline to an uneconomical level, the stumps can be allowed to regrow into a woodlot again. Rotational woodlots presents an excellent example of a sequential and/or intermediate tropical agroforestry system with great promise of reducing deforestation as well as increasing crop production in a sustainable manner (Nyadz (2002); TAFORI, 2004; Akinnifesi *et al.,* 2008). Establishment of rotation woodlots may go through various phases from the establishment, fallow and post fallow alternating with crops (Kimaro *et al.,* 2007; Maduka, 2007). Additional environmental and social benefits include soil conservation, improved water quality, enhanced biodiversity, and income diversification through firewood, medicine, bees and non timber forest products (Onyango *et al.*, 2010; Oyebade *et al.,* 2010; Kiptot and Franzel, 2011).

**Alley cropping**

Alley cropping involves growing crops (grains, forages and vegetables) between trees planted in rows, for example rows of maize interspersed with rows of *Leucena.* It has generated a lot of interest among agroforestry researchers because it aims to increase crop yields, maintain soil fertility, and provide a sustainable alternative to shifting agriculture (Quandt, 2010). The spacing between rows is designed to accommodate the mature sized

trees while leaving room for the planned alley crops. The alleyways need to be wide enough to let in sufficient light even when the trees have matured. Alternatively, the cropping sequence can be planned to change as the growing trees decrease the available light. For example, beans or maize could be grown when the trees are very small; then, as the tree canopies close, forages could be harvested. When the trees are fully grown and the ground is more shaded, grazing livestock or shade tolerant crops like mushrooms or ornamental ferns could occupy the alleyways (Beetz, 2002). The woody plants from the tree rows are regularly cut, leaves and twigs are used as mulch on the cropped alleys in order to reduce evaporation from the soil surface, suppress weeds and or add nutrients. Fuelwood, building poles, food and fodder can be obtained as the main output (Lulandala, 2010). Research results from the Mafiga field station (Morogoro) indicated that a well managed alley farming with 3 333 trees per hectare could produce up to 71 $m^3$ per hectare in 2 years in addition to normal crop yields. This amount is sufficient for an annual fuelwood need of over two households (Lulandala, 2010).

## 2.3 Contribution of Various Sources of Household Food Security and Income Generation to the Local Communities

Agroforestry plays a role in increasing farm income, tree species diversity, fodder and fuel wood (Regmi, 2003; Akinnifesi *et al.*, 2008). In Rwanda, Paul (2011) reported that agroforestry activities in woodfuel plantations contributed by generating and sustaining benefits in terms of improved livelihoods. According to Fernandes *et al.* (1984), for example, fuelwood production in the *Chagga* homegardens of Tanzania is estimated at 1.5-3 $m^3\ ha^{-1}\ year^{-1}$. Assuming a minimum consumption of $1m^3$ per adult $year^{-1}$ and if each family requires 4-6 $m^3 year^{-1}$, homegardens supply 25 - 33% of the household fuel wood requirements. Kebebew and Urgessa (2011) found that agroforestry helped households to attain food security and income for about 72% while the remaining 28% were from

agriculture, livestock and off farm activities. Edward (2003) reported of homegardens component contribution of 67.7% crops, 29% livestock and 3.6% trees to the livelihoods of local communities in Rombo District, Kilimanjaro Region. Regmi (2003) reported that agroforestry sources contributed highest proportion of 60% of the total household income livelihood while 39.6% came from off farm activities.

Employment is also contributing to household food security and income generation of the rural communities. Low income individuals living in developing countries regularly engage in a variety of formal and informal labour activity to support themselves and their families. Monde *et al.* (2008) reported that food security of most rural households in South Africa was primarily based on purchasing food by the income derived from employment or claiming from the state.

The livelihood of smallholder farmers improved through market development and rural employment, thus, supported through business development. Small businesses along with management skills and book-keeping for interested beneficiaries will help to reduce poverty as well as improving food and income livelihood. These small businesses include the processing of farm produce (crop processing, fish and flower drying and trading) and non-farm businesses such as groceries, snack production, bamboo mats and roofing materials production and marketing, construction tailoring and mechanics (BCIS, 2012). If well used and managed, they produce income for buying food and other household needs, thus making an important contribution to food and income.

Judged by the households, agriculture is said to be the most important local economic activity even though its contribution to income is less than 5% (Monde *et al.*, 2008). Myaka *et al.* (2003) reported the importance of agriculture in income generation to the

local communities in Tanzania. Kaukab and Chakravartii (2011) noted that market failure and the inability of the farmers to benefit from cheap inputs such as fertilizers and falling prices of the farm products, force them to abandon farm based production practices and shift to other occupational practices.

In Tanzania, there are 21 million cattle (Njombe *et al.*, 2012). Livestock generates regular income and contribute to the household food security throughout the year (Jan *et al.*, 2011). In Kibaha District, Coast Region, Tanzania, food and income contributed by livestock were 30.7% and 27.7% respectively (Shalli, 2003). USAID (2009) reported of poor *masika* rains in combination with the several successive seasons of below normal rainfall during the 2005-2009 periods and resulted in poor pastures and browse and decreased livestock productivity in pastoral areas, thus, triggering abnormal migration of pastoralists and their herds in search for pastures and water. Migration of livestock has most likely decreased household income from livestock products (milk, meat and skin) that provide income for food and non food household needs. Abnormal migrations have resulted in long trekking distances, deteriorating body conditions and increased livestock mortality.

Trees provide farmers with a lot of useful goods, like fruits to eat and sell, feed for their animals and compost for their soil fertility but the forests and tree resources, are being severely diminished by farming, animal husbandry, and fuelwood consumption, all of which are essential to the well being of many communities (Akinnifesi *et al.*, 2006; Mtuya, 2006; Hill, 2007; Sileshi *et al.*, 2008; Oyebade *et al.*, 2010). For example, the collection of indigenous fruits contributes between 5.5% and 6.5% of the total household income in the rural communities of Southern Africa (Akinnifesi *et al.*, 2008). Non-timber forest products such as fruits, medicinal products, mushrooms, honey, caterpillars, flying

termites and bush meat from the miombo woodlands are central to the livelihoods of both rural and urban dwellers (Makonda and Gillah, 2007). Over 80% of the rural communities in Southern Africa depend on medicinal plants for most of their health needs (Sileshi *et al.*, 2007). The miombos are also, food providers such as honey and edible caterpillars (Sileshi, 2007; Kalaba *et al.*, 2010). However, caterpillars are becoming extinct locally due to unsustainable means of harvesting it as well as the host plants. Wood is also an important source of materials for construction such as poles and ropes. *Brachystegia* and *Bauhinia* species have been reported to be important due to their strong fiber that is also easy to peel (Kalaba *et al.*, 2010).

## 2.4 Factors Influencing the Adoption of Agroforestry and Measures Required for Improvement

### 2.4.1 Factors promoting the adoption of agroforestry

Availability of transportation networks promoted farmers to engage themselves in agroforestry practices, due to the simplicity in the transportation of people and their farm products to homes and market places.

Farms that had soil erosion control structures such as fodder and trees/shrubs along the boundary and in mixed intercropping, maintain their soil fertility. Observation by Oyebede *et al.* (2010) showed that there is a replacement of soil fertility through manure in agrosilvopastoral system practice.

Agroforestry products markets and marketing infrastructure, as recommended by the WAC (2009), play a major role in the adoption rate. Well developed input and product markets enables smallholder farmers get premium prices for their farm produce (WAC, 2009; Kaukab and Chakravartii, 2011). With access to market information, farmers can

greatly reduce losses due to lack of buyers as they will be able to make informed decisions about when to produce, what to produce, for whom to produce and when and where to sell their produce (Wiskerke, 2008).

Food security extends using natural woodlands for browsing and fodder during drought periods (Chirwa *et al.*, 2008). Due to these advantages some farmers have chosen to practice agroforestry for firewood and fodder production. Access to homegrown fodder and firewood from the prunings, directly benefit women as it frees their labour for other productive enterprises (Kiptot and Franzel, 2011). Fodder trees can be used in smallholder zero grazing system in ways that supplement or substitute commercial feeds (Jamal *et al.*, 2006).

High population density has put a lot of pressure on land as more of it is required for settlement (Musotsi *et al.*, 2008). With a small piece of land some farmers have chosen to grow varieties of tree/shrub species of high quality products with different agricultural products and/or livestock depending on their needs. As population pressure around the resources increases, there is a reciprocal demand for food and income. This results in the clearing of natural resources to provide land for crop production and grazing of animals. Agroforestry systems, particularly those in homegardens have been reported to be efficient where populations have reached high peaks due to their high productivity (Nair, 1994; Parwada *et al.*,2010).

Education is an important tool for enhancing agroforestry technologies adoption (Buyinza and Wambede, 2008; Quandt, 2010). Currently over 6000 farmers are involved in on farm testing of indigenous fruit trees in the field and homesteads. More than 12,000 farmers were trained in nursery establishment and about 5000 individual farmers are managing

their own nurseries in Malawi, Mozambique, Tanzania, Zambia and Zimbabwe (Akinnifesi *et al.*, 2006).

Firewood need in Tanzania promotes the adoption of agroforestry. The collection, use, and/or sale of fire wood is important for food and income generation. The rural households are in the use of firewood energy for cooking and heating (Quandt, 2010). For example, agroforestry supplies trees and shrubs for firewood and charcoal for cooking (Quandt, 2010). The majority of the respondents 79% reported improvement in firewood supply after agroforestry interventions in Dhading District, Germany (Regmi, 2003).

Ffolliott (2005) suggested that water harvesting and water spreads techniques that provide irrigation water on a seasonal basis or longer periods of time, represent one set of possibilities to promote homegardens. Monde *et al.* (2008) reported that the yield of crops grown increased from 40% to 70% after the water harvesting system was introduced in South Africa. Agroforestry products like firewood, lumber and poles were used for construction (Quandt, 2010). Ham and Theron (2010) reported that agroforestry provides tree products that would have otherwise been collected from the forest.

### 2.4.2 Factors limiting the adoption of agroforestry

Although agroforestry contribution to household food security and income generation have been reported to be higher compared to alternative practices, it has several factors which if not taken into consideration, can cause detrimental effects to the efforts of promoting the practice and hence limit its adoption.

For example, households found difficult to practice agroforestry technologies due to drought. In year 2009, for example there was drought and households received food aid

from the Tanzanian Government (Quandt, 2010). Unavailability of water resources for irrigation is a limiting factor for cultivation. Drought prevalence has deterred farmers from adopting the practice as it would be difficult to establish the trees under such harsh conditions (Parwada *et al.*, 2010; vanStraaten *et al.*, 2010). Homegardens in South Africa are characterized by rain fed farming systems, whereby dry periods affect the poor households because they lack income to replace food from own production with purchased food (Monde *et al.*, 2008). Agroforestry research and cost effective irrigation are urgently needed in order to reduce the production risk facing farmers, especially smallholders (Quandt, 2010).

Lack of knowledge of agroforestry has also been reported to be another factor that hinders engagement in agroforestry. Knowledge provides farmers with skills and ability to use high yielding varieties, insecticides and pesticides (Quandt, 2010; Kalaba *et al.*, 2010). Trained farmers adopted agroforestry more than untrained farmers (WAC, 2009; Parwada *et al.*, 2010). Knowledge increases farmer's ability to obtain process and use adoption information. Agroforestry is a knowledge and management intensive practice. In Uganda, it was found that little or no agroforestry knowledge provided by government and private sectors resulted in low yields due to poor farming practices (Buyinza and Wambede, 2008).

Also, the presence of the vegetation on the land management unit may attract wild animals such as monkeys and rodents that can, in turn, cause problems to the associated crops (Lulandala, 2010). Trees provide readily resting, food and nesting grounds for birds. The crop residues and trees encourage pathogen infestations and cause disease problems to systems. If necessary the use of insecticides and pesticides is important (Parwada *et al.*,

2010). The study by Irshad *et al.* (2011) reported of insects, pests and diseases as being negative impacts of tree planting in agroforestry.

Seeds/seedlings accessibility is a critical factor that affects the adoption of agroforestry technologies (WAC, 2009; Parwada *et al.*, 2010). In the absence of the seed/seedlings, rural people are left with no option but to abandon the technologies despite their significance which can be established scientifically. For example, in Malawi, the number of farmers using the *Gliricidia*-maize intercropping is relatively low as compared to those using *Tephrosia spp.*, *Sesbania sesban* and *Cajanus cajan* (Akinnifesi *et al.*, 2008). Mtuya (2006) found that 14% of farmers had no trees on their farms due to lack of seeds and seedlings of proper tree species. Mtuya (2006) reported that, large numbers of cattle herds found grazing on crop farms, were problem that limited farmers adopting agroforestry. Ham and Theron (2010) indicated that 60% of woodlots were being damaged by cattle.

Farmers with good financial status can readily adapt new technologies than those with limited source of income. Monde *et al.* (2008) reported of financial problems hindering the adoption of homegardens in South Africa. Rural households tend to diversify their sources of livelihood through agroforestry to afford adoptions as well as meeting the basic needs (Nair, 1984). Cultural acceptance of new technologies and access to sufficient source of income are equally important.. According to Ssemwanga *et al.* (2004), high prices in agroforestry are due to high transaction costs caused by a thin market and high transaction costs caused by other running costs. Rahim *et al.* (2005) reported that agroforestry adoption was determined not only by structural factors like farm size and farm fragmentation, but also by factors that affect the opportunity costs of labour. Bonifasi (2004) reported that 91% of the smallholder farmers in Lushoto District, Tanga Region,

Tanzania, contended prices of the farm inputs were expensive and that the majority could not afford.

A survey conducted in Luhungo and Tandai villages in rural Morogoro by MNRT (2003) revealed that land shortage and tenure were a big constraint. Land sizes per household were only 1.2 ha and 2.0 ha respectively. Land tenure refers to both ownership and utilization rights, which are very complex issues in Africa and differ widely from one part of the country to another (Cook and Michael, 1991). Nair (1993) reported that there was less likelihood of adoption of long term practices such as agroforestry in areas where land tenure systems do not guarantee continued ownership and control of land. Armele (1995) reported that in Brukina Faso, the law categorically states that anyone has the right to harvest the fruits of his/her own labour. Therefore, land owners forbid migrants to plant trees on leased lands. In India possession of a land is said to be a necessary condition for the adoption of agroforestry (Alavalapati *et al.*, 1995). Agroforestry practices are more negatively affected by land and tree tenure arrangements (Ajayi *et al.*, 2007). According to Ajayi *et al.* (2007) and Akinnifesi *et al.* (2008) farmer acceptability and improved adoption of agroforestry will be influenced by the extent to which efforts are taken to meet these challenges.

### 2.4.3 Measures required for agroforestry adoption improvement

Measures to be taken to improve agroforestry adoption in the rural areas include provision of water for irrigation especially during drought `periods. Extension services are served mainly to increase awareness of the multipurpose potential of agroforestry (Bukenya *et al.*, 2007). Lack of extension workers and insufficient time for farmers to learn seriously affect the adoption of agroforestry. Appropriate agroforestry methods and experience enhance the ability to reach the poor farmers (Mgeni, 2008). Agroforestry training avail

opportunities to government extension staff to provide information and scale up the technologies to farm communities (WAC, 2009). Buyinza *et al.* (2008) reported that extension methods preferred by farmers included group discussion, field days, field tours, village meetings, radio and individual methods.

Multi-disciplinary co-operation with other disciplines like livestock, agriculture, community development and others should be encouraged for more advice to promote agroforestry activities (Irwin, 1997). Non-governmental organizations (NGOs) have a great role in knowledge provision i.e. ensured sustainable extension services, even after the termination of their activities (Shilabu, 2008). NGO's and government agencies are needed to disseminate agroforestry to farmers in different parts of the country (Irwin, 1997; Buyinza *et al.*, 2008). Sonoko (2001) reported that farmer to farmer extension approach was efficient, reached over 75% farmers in Tarime District, Mara Region, Tanzania. Involving of NGOs in knowledge provision increases the effort on knowledge dissemination.

In agroforestry, woody and non-woody plant mixtures involve choices of trees/shrubs, crops and/or animal/pasture species. One of the nearest sources for accessing seed and/or seedlings is the government run nurseries (Regmi, 2003). There is little or no institutional structure to make agroforestry seeds available in Tanzania (WAC, 2009). Measures are required to overcome lack of planting materials (seeds, seedlings or cuttings) and lack of information in order to improve agroforestry adoption (SWF, 2005). Available nurseries, central in various parts of the country, have very low seedling outputs and unable to meet demands of the surrounding farmers (Kiwale, 2002). For that reason, rural communities should be persuaded and assisted to establish their own tree nurseries including provision

with desirable germplasm and ensure that the products are accessible to smallholder farmers.

Also, farm credits play part in enhancement of adoption of agroforestry technologies and cause difference between per capital incomes, food security and nutritional status of credit program members and non members (Diagne, 1998). Agroforestry farmers can enter into contracts with companies to provide various products they produce and the companies in return provide loans, small and medium credits, seedlings, advice and make advance payments for future products (Ham and Theron, 2010).

According to (Quandt, 2010), the initial capital needed to start agroforestry is very little but its unavailability effectively limits the adoption in the rural areas. The credit agencies should facilitate farmers, especially the poor, in accessing capital. Additionally, it is necessary to disseminate information of capital sources and loan procedures. Capital should be provided, both in cash and in kind.

Bonifasi (2004) reported that the farmers practicing agroforestry, managed to arrest the problem of soil erosion by stopping the farmers system of free livestock grazing which was accelerating the problems by planting more trees, and addition of animal manure.
Market and marketing strategy of agroforestry products need to be assessed and innovated as the measures to improve agroforestry adoption. Smallholder farmers need to be empowered to organize themselves into producer organizations to enable them to form strong linkages with market actors and raise their bargaining power as the element to ensure fair market prices and thus improve their income as well as their food security (Kashuliza *et al.*, 2002). Wiskerke (2008) reported that farmers with knowledge of market prices and market opportunities will have adequate negotiation power in their agroforestry

products. The study done in Western Kenya by ICRAF (2002) revealed that the implementation of Agroforestry technologies was focused on both soil types and market situation. Other measures to be taken to improve agroforestry adoption in the rural areas include land availability and accessibility (i.e. roads) for transporting their products from the farms to markets or from the farms to their homes.

# CHAPTER THREE

## 3.0 MATERIALS AND METHODS

### 3.1 Materials

#### 3.1.1 Location of the study area

This study was conducted in Arumeru District, Arusha Region, northern Tanzania. The district is located between longitudes 35° 37 ' and 35° 47 ' East and latitudes 3° 17 ' to 3° 27 ' South. The district is bordered by the Monduli District to the north and west. Hai District to the east and the Kiteto District to the south. Currently Arumeru District is divided into two administrative councils, the Arusha District Council (ADC) and Meru District Council (MDC) (DADPs, 2012). Administratively, Arusha DC comprises of 3 divisions with 20 wards, 75 villages and 64 339 households while Meru DC is divided into 3 divisions, 17 wards, 69 villages and 48 768 households. Up to the time when data were collected the two district councils were under one district administrative director.

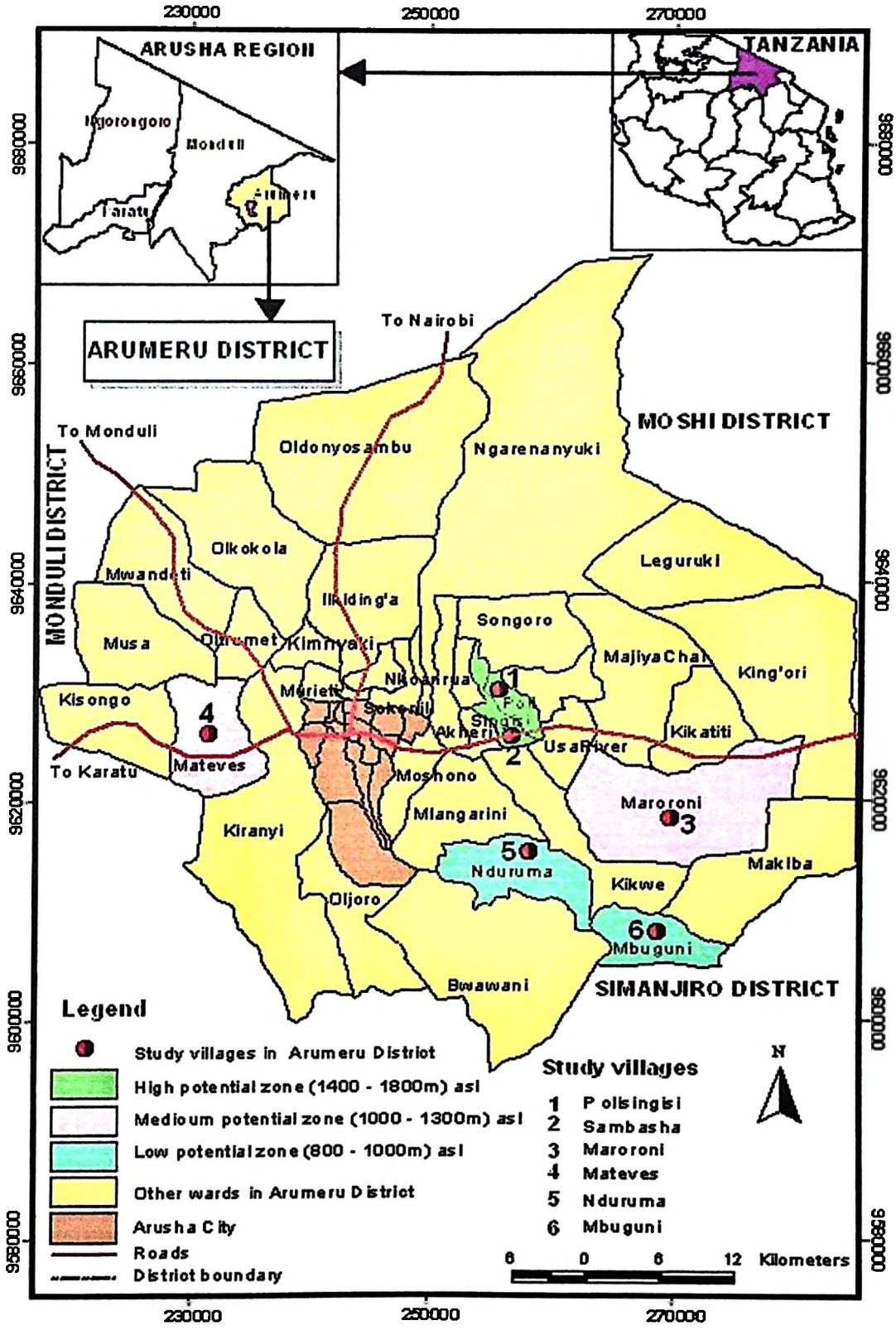


**Figure 1: Map showing the location of Arumeru District**

### 3.1.2 Description of the study site

**Population**

According to the 2002 census, the total population of the Arumeru District was 516 814 individuals whereby, 253 143 were males and 263 671 were females (URT, 2003). The dominant tribes are Wameru and Waarusha (Laizer, 2000).

**Geology and soil**

The soil of Arumeru District is volcanic in origin, resulting from Mount Meru, which is an extinct volcano (SCAPA, 1998). The rocks are volcanic, varying from coarse vesicular gray lavas, to fine grained basalts. These are overlain by the deep soil originating from volcanic ash, and generally classified as andosols. As a consequence the soils erode easily and have low bearing strength. The soil is very loose when dry, and when loosened by the feet, hooves or wheels can easily be eroded, if disturbed is highly susceptible to soil erosion. Plains with low rainfall are used as rangelands with dense livestock populations. Most fertile land with high rainfall is on the moderate and steep slopes of Mount Meru and associated with more land under cultivation.

**Climate**

The area has a bimodal rainfall pattern with long rains from March to May, and short rains from November to December. The average annual rainfall varies from 800 mm to 1 500 mm. The temperature ranges between 15°C and 28°C during the year so the climate is generally cool (Shio, 2004). Extreme cases do not occur and frost occurrence has never been experienced except at higher altitudes beginning 1 600 meters above sea level. Topography of the area is highly influenced by Mount Meru hence cool temperatures and heavy rains. The area has few steep slopes often exceeding 20% with the exception of steep slopes towards higher altitudes. In most areas the slopes are moderate. Numerous

perennial and seasonal streams such as Engarenarok, Temi, Nduruma, Tengeru, Malala, Maji ya Chai and Usa Rivers dissect the slopes and flow down the mountain (Makawia, 2003).

**Vegetation**

The steep slopes of Mount Meru are surrounded by both indigenous and planted forests. The southern side of the steep slopes has a well developed mountain forest belt, while some indigenous forests are protected as national, district, or village reserves (Mwakatobe, 2001). In general, more than half of the district is cultivated and the rest is forest, bushes and open grasslands (Laizer, 2000).

**Agro-ecological zones and district economic activities**

Arumeru District has three agro-ecological zones namely: the high potential areas; the medium potential areas; and the low potential areas. The term 'high potential' is used to distinguish areas that depending on the characteristics of rainfall pattern, temperature and soil fertility, can be used for intensive agricultural production. The term 'highland' (normally a physically identified area recognized by altitude) is also commonly used to describe the high potential fertile mountainous areas. The high potential areas are densely populated with volcanic ash soil (nitrosols), that are moderately developed and of bimodal rainfall pattern ranging between 1 000 and ! 500 mm per annum. The areas have high altitudes of 1 500 m or more, above sea level (a.s.l.) (Kajembe *et al.*, 2005). Both natural and planted forests surround the steep slopes of Mount Meru (Mwakatobe, 2001). The eastern slopes of Mount Meru are densely populated due to relatively more fertile soils and higher levels of precipitation. Crops grown are mainly coffee, bananas, fruits (avocados, citrus and pawpaws). Animals kept are mainly exotic and mixed breeds of dairy cattle, which are stall fed because people living in these areas tend to concentrate on

small family farms of about 0.8 ha (on average) and produce just enough food for consumption with a very limited surplus for sale (Kajembe *et al.*, 2005). Even though raising livestock as a livelihood strategy is the choice for the households, the relatively moderate net income level that it provides implies that it is more a means of subsistence than of wealth accumulation (Ueda, 2007).

Moreover, the term 'medium potential areas' refers to land resources with physical limitations for intensive small scale farming compared to the high potential areas. Crops grown are maize intercropped with beans, coffee, and bananas with a semi extensive livestock system. Livestock are mainly free grazed and few are stall fed. The middle zone is once the primary coffee production area, and it is populated with homesteads, or compound forms of relatively intense cropping of bananas and coffee; in addition, stall feeding livestock is raised and seasonal crops are grown in fields (Nkonya *et al.*, 1991; Ueda, 2007). Households in the middle zone are relatively free from the transport constraints. They import fodder from lower areas for the purpose of rearing dairy cattle (Nkonya *et al.*, 1991; Ueda, 2007). Precipitation is slightly lower than that found in high potential areas and ranges from 800 to 1 000 mm per annum (Kajembe *et al.*, 2005). Altitude ranges from 900 to 1 500 m a.s.l. Soils in these areas are brown, thus less leached and slightly more fertile than soils in the low potential areas (Kajembe *et al.*, 2005).

The 'low potential areas' also commonly referred to as 'lowlands', consist mainly of plains surrounding the mountains with altitudes of 900 m a.s.l. or less (Kajembe *et al.*, 2005). These lowland areas are relatively more dry compared to the high and medium potential areas. The land is used increasingly for seasonal crops and grazing with decreasing elevation. In addition, bananas surround the homesteads where irrigation channels are available. The dairy cattle raised and milk production occur only at

subsistence level (Ueda, 2007). Also, local inhabitants have no other choice but to rely on the production of staple crops, non-farm activities, and other agro-natural extractions (Ueda, 2007). The amount of rainfall is less than 800 mm per annum and it is normally erratic and bimodal (Nkonya *et al.*, 1991). The soil is volcanic ash, more developed than in high and medium potential areas. Maize is intercropped with beans. Wheat and barley are grown in western areas. Livestock rearing is quite extensive and concentrates mainly on raising local cattle breeds (zebu), with very few improved dairy cattle. Goats, sheep, donkeys and chicken are also kept (Nkonya *et al.*, 1991). Soil erosion is quite pronounced due to the vulnerability of the volcanic soils and rolling topography.

## 3.2 Methods

### 3.2.1 Sampling procedures

Both purposive and random sampling techniques were used in the selection of respondents from the population under study to capture the representative sample. The area was stratified into three agro-ecological zones based on altitude namely the high potential zone (1 400- 1 800 m a.s.l), the medium potential zone (1 000-1 350 m a.s.l) and the low potential zone (800-1 000 m a.s.l). From each agro-ecological zone, two wards were selected at random. From each selected ward, one village was chosen at random. Then 20 households were randomly selected from each selected village to make a total sample of six wards, six villages, and 120 households. Random selection was done to avoid biasness and provide equal opportunities for all households to be selected for inclusion in the total population sample of the households which is in correspondence with the observation by Matata *et al.* (2001) who recommended a sample size of between 80 to 120 respondents when dealing with social economic studies in the Sub-Saharan African households. The household in each selected village were obtained from the village household register.

### 3.2.2 Data collection

Both primary data and secondary data were collected. Secondary data were collected from different sources of literature, including periodic reports, books, journals and publications from various libraries and electronic searches. Primary data collection was carried out using three approaches as follows:

**Reconnaissance survey**

Prior to the actual data collection, a reconnaissance survey was conducted. This was considered as important because it enabled the researcher to introduce herself to the respective district, division, ward and village leaders, pre-testing of data collection instruments and get a general picture and familiarity with the study area. Also during reconnaissance survey information about agriculture, livestock, forest, beekeeping and other resource management systems in the district, water availability, communication services, population and economic activities were collected. Initially from each agro-ecological zone, one ward was randomly selected and from each selected ward, one village was selected randomly. Then three households were randomly selected from each of the three selected villages in order to make a total sample of nine households for the preliminary survey and the results were used to modify the questionnaire to fit the actual conditions. Also, during this process, the key informants were identified and the actual sample households for the study were selected.

**Social survey**

Primary data were collected from the field through structured questionnaires with closed and open ended questions (Appendix 1). Field observations and checklists of probe questions for key informants and focus group discussion methods (Appendix 2) were used in order to allow cross-checking of the collected information (triangulation) (Olsen, 2004).

Data which were collected included household sources of food and income, total quantity of household production of each source, amounts spent for food and amount spared for cash generation from each source, types of agroforestry systems and technologies and their adoption levels, factors influencing agroforestry adoption and measures required for improvement were collected.

**Field survey**

Apart from interviewing individual households, visits to respective farmer's fields were done to have personal observations of agroforestry systems and technologies in place in the area, to identify systems components, their arrangements and management practices. Field survey involved the observation of common tree species found in the area and their intensification, visit on the firewood harvests, woodlot and fodder banks. Transect walks crossing village farms were done and sample plots were established along them at constant intervals for determining component species and their intensification.

### 3.2.3 Data analysis

Tables of treatment means were used to report different data obtained during the study. Analysis of Variance (ANOVA) of the data using the Completely Randomize Block Design (CRBD) statistical model, was performed and the F-test was made at both the 0.05 and 0.01 significance levels in order to determine the levels of differing treatment means. The separation and ranking of the significantly differing means were based on the Least Significant Difference (LSD). The SAS statistical package was used.

# CHAPTER FOUR

## 4.0 RESULTS

### 4.1 Various Sources of Household Food Security and Income Generation of the Local communities of Arumeru District

#### 4.1.1 The sources of household food security

The results on the various sources of household food security for the local communities in Arumeru District are presented in Tables 1 with the raw data and ANOVA table in Appendices 3 and 4 respectively. It was noted that agroforestry was the district's most important source of the communities food security followed by the business and agriculture.

**Table 1: Various sources of household food security of the local communities in Arumeru District**

| Source | Household food | |
|---|---|---|
| | Frequency | Percentages (%) |
| Agroforestry | 120 | 71a |
| Business | 13 | 8b |
| Agriculture | 11 | 6bc |
| Forest | 5 | 3bc |
| Employment | 5 | 3bc |
| Relatives | 5 | 3bc |
| Honey | 5 | 3bc |
| Livestock | 4 | 2bc |
| VICOBA | 2 | 1c |
| **Total** | **170** | **100** |

Values in the same column that are followed by a different letter differ significantly ($P< 0.05$). Least Significant Difference (LSD) = 3.0302

### 4.1.2 Sources of household income generation

The results on the sources of household income generation for the local communities in Arumeru District are presented in Table 2 with the raw data and ANOVA table in Appendices 5 and 6 respectively. The district's most important source of the communities income generation were indicated to be agroforestry followed by business and employment.

**Table 2: Various sources of household income of the local communities in Arumeru District**

| Source | Household income | |
|---|---|---|
| | Frequency | Percentages (%) |
| Agroforestry | 119 | 59a |
| Business | 33 | 16b |
| Employment | 17 | 8c |
| Agriculture | 11 | 6cd |
| Livestock | 6 | 3de |
| Relatives | 5 | 3de |
| Honey | 5 | 3de |
| Forestry | 3 | 1e |
| VICOBA | 2 | 1e |
| **Total** | **201** | **100** |

Values in the same column that are followed by a different letter differ significantly ($P < 0.05$). Least Significant Difference (LSD) = 2.7745

## 4.2 Agroforestry Systems and Technologies in Use by the Local Communities in the District

### 4.2.1 Agroforestry systems

Agroforestry systems in use by the local communities in Arumeru District are presented in Table 3 with the raw data and ANOVA tables in Appendices 7 and 8 respectively. It will be noted that agrosilvopasture was the leading among the most widely used agroforestry system, followed by agrosilvicultural system.

**Table 3: Agroforestry systems in use in Arumeru District**

| System | Frequency | Percentages (%) |
|---|---|---|
| Agrosilvopasture | 106 | 78a |
| Agrosilviculture | 13 | 10b |
| Silvopasture | 8 | 6bc |
| Aposilviculture | 4 | 3c |
| Agroaquosilvopasture | 3 | 2c |
| Agroaposilvopasture | 2 | 1c |
| **Total** | **136** | **100** |

Values in the same column that are followed by a different letter differ significantly ($P < 0.05$). Least Significant Difference (LSD) = 2.6503

Agroforestry systems adopted in each agro-ecological zone in Arumeru District are presented in Table 4 with the raw data and ANOVA tables in Appendices 9-14. In all agro-ecological zones of Arumeru District, the agrosilvopastoral system was the most dominant practice of the local communities. Agrosilvicultural system was second most widely adopted agroforestry system in the lower and upper zones while silvopastoral system was the second most commonly adopted system in the medium zone.

**Table 4: Agroforestry systems adopted in each agro-ecological zone in Arumeru District**

| Zone | System | Frequency | Percentages (%) |
|---|---|---|---|
| Lower | Agrosilvopasture | 18 | 78a |
| | Agrosilviculture | 2 | 9b |
| | Silvopasture | 1 | 4b |
| | Aposilviculture | 1 | 4b |
| | Agroaposilvopasture | 1 | 4b |
| | **Total** | **23** | **100** |
| Medium | Agrosilvopasture | 34 | 76a |
| | Silvopasture | 5 | 11b |
| | Agrosilviculture | 3 | 7b |
| | Agroaquosilvopasture | 2 | 4b |
| | Aposilviculture | 1 | 2b |
| | **Total** | **45** | **100** |
| Upper | Agrosilvopasture | 36 | 80a |
| | Agrosilviculture | 6 | 13b |
| | Silvopasture | 1 | 2b |
| | Aposilviculture | 1 | 2b |
| | Agroaquosilvopasture | 1 | 2b |
| | **Total** | **45** | **100** |

Values in the same column that are followed by the different letters differ significantly ($P < 0.05$)

### 4.2.2 Agroforestry technologies

Agroforestry technologies adopted in the various parts of Arumeru District are presented in Tables 5 and 6 with the raw data and associated ANOVA tables in Appendices 15-22. It was noted that homegardens, mixed intercropping, boundary planting and livefence were the most widely used and together accounted for 83% of all agroforestry technologies used

in the district, with the former being most preferred in the upper and middle agro-ecological zones while the latter in the lower agro-ecological zone.

**Table 5: Agroforestry technologies in use in various parts of Arumeru District**

| Agroforestry technology | Frequency | Percentages (%) |
|---|---|---|
| Homegardens | 79 | 33a |
| Mixed intercropping | 73 | 30a |
| Boundary and live fence | 48 | 20b |
| Fodder bank | 19 | 8c |
| Rotational woodlot | 15 | 6cd |
| Alley cropping | 7 | 3cd |
| **Total** | **241** | **100** |

Values in the same column that are followed by a different letter differ significantly ($P < 0.05$). Least Significant Difference (LSD) = 7.1213

**Table 6: Agroforesty technologies adopted in various agro-ecological zones in Arumeru District**

| Agro-ecological zone | Technology | Frequency | Percentages (%) |
|---|---|---|---|
| Lower | Intercropping | 39 | 54a |
| | Boundary and live fence | 14 | 19b |
| | Rotational woodlot | 6 | 8bc |
| | Homegardens | 6 | 8bc |
| | Alley cropping | 4 | 6c |
| | Fodder bank | 3 | 4c |
| | **Total** | **72** | **100** |
| Medium | Homegardens | 33 | 53a |
| | Intercropping | 19 | 31b |
| | Boundary and live fence | 5 | 8c |
| | Rotational woodlot | 3 | 5c |
| | Fodder bank | 1 | 2c |
| | Alley cropping | 1 | 2c |
| | **Total** | **62** | **100** |
| Upper | Homegardens | 40 | 37a |
| | Boundary and live fence | 29 | 27ab |
| | Intercropping | 15 | 14bc |
| | Fodder bank | 15 | 14bc |
| | Rotational woodlot | 6 | 6c |
| | Alley cropping | 2 | 2c |
| | **Total** | **107** | **100** |

Values in the same column that are followed by the different letters differ significantly ($P < 0.05$)

## 4.3 Extent of Agroforestry Contribution to Household Food Security and Income Generation of the Local Communities in the District

### 4.3.1 Contribution of various sources to household food security for the local communities

The contribution of various sources to household food security of local communities in Arumeru District are presented in Table 7 with the raw data and ANOVA tables in Appendix 23. It was noted that agroforestry contribution to food security was the highest among the various sources alone accounting for nearly 89% of the household food requirements for the communities in the district.

**Table 7: Contribution of various sources to household food security for the local communities in Arumeru District**

| Sources | Average income (Tsh/hh/yr) | % average |
|---|---|---|
| Agroforestry | 1,124,940 | 88.6a |
| Businesses | 64,754 | 5.1b |
| Agriculture | 46,978 | 3.7bc |
| Livestock | 17,776 | 1.4bc |
| VICOBA | 5,079 | 0.4c |
| Relatives | 3,809 | 0.3c |
| Employment | 2,539 | 0.2c |
| Forest | 1,270 | 0.1c |
| **Total** | **1,269,684** | **100** |

Values in the same column that are followed by a different letter differ significantly ($P < 0.05$). Least Significant Difference (LSD) = 4.4232

### 4.3.2 Contribution of various sources to income generation of local communities

The contribution of the various sources to household income generation of the local communities in Arumeru District are presented in Table 8 with the raw data and ANOVA tables in Appendix 24. It was noted that agroforestry was the highest contributor to income generation among the various sources. Agroforestry alone accounted for 84% towards the income generation for the communities in the district.

**Table 8: Contribution of various sources to household income generation for the local communities in Arumeru District**

| Sources | Average Income (Tshs/hh/yr) | % average on income |
|---|---|---|
| Agroforestry | 654,353 | 84.0a |
| Agriculture | 34,154 | 4.4b |
| Employment | 31,049 | 4.0b |
| Business | 28,720 | 3.7bc |
| Livestock | 18,629 | 2.4bc |
| Relatives | 3,881 | 0.5c |
| VICOBA | 3,881 | 0.5c |
| Forest | 1,552 | 0.2c |
| **Total** | **776,219** | **100** |

Values in the same column that are followed by a different letter differ significantly ($P < 0.05$). Least Significant Difference (LSD) = 3.4878

## 4.4 Factors Influencing the Adoption of Agroforestry and Measures Required for Improvement

### 4.4.1 Factors promoting the adoption of agroforestry

The results in Table 9 with the raw data and ANOVA tables in Appendices 25 and 26, show the different factors that are promoting the adoption of agroforestry in Arumeru

District. Availability of transportation networks (roads) followed by soil fertility, market and fodder needs were the most motivating factors for adopting agroforestry in the district.

**Table 9: Factors that promote the adoption of agroforestry in Arumeru District**

| Factors | Frequency | Percentages (%) |
|---|---|---|
| Transportation networks (i.e. roads) | 39 | 29.5a |
| Soil fertility | 20 | 15.2b |
| Market availability | 18 | 13.6bc |
| Fodder need | 17 | 12.9bc |
| Land scarcity | 8 | 6.1cd |
| Population increase | 6 | 4.5d |
| Education | 6 | 4.5d |
| Firewood | 6 | 4.5d |
| Water for irrigation | 6 | 4.5d |
| Construction materials | 3 | 2.3d |
| It's custom | 3 | 2.3d |
| **Total** | **132** | **100.0** |

Values in the same column that are followed by a different letter differ significantly ($P < 0.05$). Least Significant Difference (LSD) = 3.6457

### 4.4.2 Factors limiting the adoption of agroforestry

The results in Table 10 with the raw data and ANOVA tables in Appendices 27 and 28 respectively, show the different factors that limit the adoption of agroforestry in Arumeru District. Drought followed by lack of knowledge were the most important limiting factors.

**Table 10: Factors that limit adoption of agroforestry in Arumeru District**

| Factors limiting | Frequency | Percentages (%) |
|---|---|---|
| Drought | 64 | 45a |
| Knowledge | 38 | 27b |
| Pest/disease | 11 | 8c |
| Seed/seedling | 10 | 7c |
| Animal free grazing | 8 | 6c |
| Financial constraints | 7 | 5c |
| Land scarcity | 3 | 2c |
| **Total** | **141** | **100** |

Values in the same column that are followed by a different letter differ significantly ($P < 0.05$). Least Significant Difference (LSD) = 5.1866

### 4.4.3 Measures required for improving the adoption of agroforestry in Arumeru District

Results in Table 11 with the raw data and ANOVA tables in Appendices 29 and 30 respectively, present the different measures that the local communities suggest to be needed in order to enhance the adoption of agroforestry in the district. Provision of water for irrigation was the most critically need measure for such improvement. Other important measures include increased extension services to farmers, farmer training and assurance of market for various agroforestry products.

**Table 11: Measures required for improving adoption of agroforestry in Arumeru District**

| Measure | Frequency | Percentages (%) |
|---|---|---|
| Water for irrigation | 60 | 28.7a |
| Extension services | 32 | 15.3ab |
| Involving of NGO's on education provision | 26 | 12.4b |
| Provision of seeds/seedlings | 18 | 8.6b |
| Market for agroforestry products | 16 | 7.7b |
| Input on time | 15 | 7.2b |
| Capital | 13 | 6.2b |
| Land provision | 9 | 4.3b |
| Transportation network | 8 | 3.8b |
| Abolition of free grazing | 7 | 3.3b |
| Farm credit | 5 | 2.3b |
| **Total** | **209** | **100** |

Values in the same column that are followed by a different letter differ significantly ($P < 0.05$). Least Significant Difference (LSD) = 9.7019

# CHAPTER FIVE

## 5.0 DISCUSSION

### 5.1 Various Sources of Household Food Security and Income Generation of Local Communities of Arumeru District

The results on the sources of household food security for the local communities in Arumeru District are presented in Table 1 with the raw data and statistical details in Appendices 3-4 respectively. The observation that agroforestry was the most dependable source of the household food security of the local communities in the Arumeru District agrees with the findings reported earlier in Bangladesh (Rahman *et al.*, 2008) and Lushoto District in north eastern Tanzania (Bonifasi, 2004). Musotsi *et al.*, (2008) and OlajideTaiwo *et al.* (2010) reported on the valuable benefits of agroforestry to the household livelihood. A unique characteristic of agroforestry is in its ability to provide food and various systems' products throughout the year and during the periods of hunger (WAC, 2009). It is an important source of livelihood to the practicing households (Ndaeyo, 2007; Zeleke, 2009; Quandt, 2010; Kebebew and Urgessa, 2011). Even vegetables are obtained from agroforestry practices (URT, 2009).

Livestock keeping are likely to be more important source of food from agroforestry (Riely *et al.*, 1999). The system's components with diversified and different fruiting periods avail products that are obtained at different times of the year and to that effect, have been used by the households to overcome food insecurity (Opala, 2011), which is among important work of food security pillars (FAO World Food Summit, 1996). Oyebede *et al.* (2010) resolved towards enhanced production and productivity through agroforestry.

Local communities of Arumeru District dependence on business as a source of livelihood. The present results are supported by the findings of Mbura (2007), URT (1991) and ILO (2003). The district is peri-urban or close to the urban environment with ready market conditions.

Agricultural production system is among important activity in Arumeru District agrees with the findings reported earlier by Swift (1988). However, agriculture is less dependable source of food security in the study area due to shortfall of the system in the need for efficient resources management approaches. It has a limited benefits per unit area, highly vulnerable to climatic changes (TFNC, 1992) and result in food insecurity FAO (1991), Kajembe *et al.* (2000), Kalaba *et al.* (2009) and Kalaba *et al.* (2010). The present results are supported by the findings of the World bank (1993) which reported on the failure of the efforts made to develop agriculture. Moreover, soil infertility dependence on expensive farm inputs and low availability of family labor lead farmers to adopt agroforestry as the alternative production system (Mtuya, 2006; Sood, 2006; Kaukab and Chakravartii, 2011).

The present results are different from the findings of Shilabu (2008) and DADPs (2012) where people still think about depending on agriculture and livestock keeping for their livelihood. Kashulinza *et al.* (2002) explained the role of agriculture to the household livelihoods. The importance of agriculture is also explained at national level whereby the Tanzanian dependence in the agricultural sector for their livelihood was reported by (Myaka *et al.*, 2003; TEP, 2011), although adequate food availability at the national level did not represent food security at the individual and household levels (Frankenberger and McCaston, 1998).

The Arumeru people seem to be less dependant on forests for their livelihoods. The district has covered with forests and woodlands (FAO, 1997; URT, 1998). The forest products that are intended to meet the day to day household needs such as firewood, fodder, medicinal requirements and construction materials are obtained from agroforestry practices (Mtuya, 2006; Akinnifesi *et al.*, 2006; Hill, 2007; Sileshi *et al.*, 2008; Oyebede *et al.*, 2010). Also, these findings agree with those of Ham and Theron (2010).

Less dependence on livestock to household food security and income generation observed in the present study agrees with the findings reported from other areas of this country (Shilabu, 2008). This is due to a number of threats including climatic change, that have made the Waarusha and Wamasai people to increasingly shift from pastoralism to agroforestry in which livestock are an important component.

The results on the sources of household income generation for the local communities in Arumeru District are presented in Table 2 with the raw data and statistical details in Appendices 5-6 respectively. The indication that agroforestry was the most dependable source of the household income generation to the local communities in the Arumeru District agrees with the findings reported earlier by (Bonifasi, 2004; Rahman *et al.*, 2008). Musotsi *et al.* (2008) reported the role of agroforestry to the household livelihood. Agroforestry makes an important source of income generation to the practicing households (Ndaeyo, 2007; Zeleke, 2009; Quandt, 2010; Kebebew and Urgessa, 2011).

Business plays an important role in income generation of the local communities of Arumeru District. The present results supported by the findings by URT (1991), ILO (2003) and Mbura (2007).

Employment dependance on by households for their income generation after agroforestry and businesses. Activity performed in a self-directed, full time and casual basis (FAO, 2011). In rural South Africa for example, food security, for some families, is attained by the income that derives from employment (Monde *et al.*, 2008). Also, FAO (2012) cited income from work as a determinant of the amount and quality of food for some households. Increase in employment, therefore, has immediate effects on households lifestyles (FAO, 2010a).

Sales of livestock and livestock products in the District provide farmers with income to purchase household necessities, also reported by Mphuru (1991), URT (2001), Wiskerke (2008) and Jan *et al.*, (2012).

Households depend on their relatives for their income generation. These are mostly the elderly, sick and disabled people (FAO, 2010b). Probably because they are no longer able to work and produce enough for their livelihood.

The Village Community Bank (VICOBA) is a source of income generation which is increasingly becoming important in Arumeru District with a promising potential for the future. Although few households are currently found to be members of the VICOBA in the district, it is most likely because they don't know their potentiality in their livelihoods.

### 5.2 Agroforestry Systems and Technologies in Use in Arumeru District

Agroforestry systems in use in Arumeru District are presented in Tables 3 and 4 with the raw data and statistical details in Appendices 7 – 14 respectively. The observation that agrosilvopastoral system was the most widely used in the district means that agricultural crop production and animal husbandry go hand in hand as equally important economic

activities of the community in the area. These findings are also supported by other studies (Nair, 1993; Lulandala, 2010; Oyebede *et al.*, 2010; Lulandala, 2012). Agrosilvopasture significantly increases systems components and products diversification that offer multiple benefits to the people involved. Similar findings have been reported earlier by (Akinnifesi *et al.*, 2008; Buyinza and Wambede, 2008; Rahman *et al.*, 2008). The set aside or reserved silvopastoral system which involves the interaction between woody perennials and grasses or pastures (Oyebede *et al.*, 2010; Lulandala, 2010; Lulandala, 2012), is also practiced in the district for the use of grazing animals during the dry season. Silvopastures are also used for income earnings (ICRAF 2006; Odoul *et al.*, 2006; Oyebede *et al.*, 2010; Irshad *et al.*, 2011). Even some families having no livestock do reserve them in exchange for money. Aposilviculture, agroaquosilvopasture and agroaposilvopasture systems were also adopted in the district. The observation made by Mwakatobe (2001) indicates that beekeeping activity yields high value products to increase farmers' income as well as food security.

Agroforestry technologies in use in the various parts of Arumeru District are presented in Tables 5 and 6 with the raw data and statistical details in Appendices 15 – 22 respectively. Among the technologies most widely practiced in the district are agroforestry homegardens which are adopted by over 33% of the farmers. This is mainly due to the fact that they are easily accessed by the community and in addition, permit fluid circulation of materials between the various components of the systems for complimentarity, enhancement and sustainability, the aspects which are in; comformity with the findings variously reported elsewhere (Nair, 1994; O'kting'ati and Mongi, 1996; Tynsong and Tiwari, 2010). Agroforestry provides food throughout the year including times of famine when herbaceous crop's are poor or fail due to drought (Nair, 1993) and Garrity (2004). Therefore, homegardens are becoming reliable alternatives for meeting fuelwood, pasture,

construction materials and income requirements (Maroyi, 2009), the factors which appear to be important motivations for the adoption of agroforestry (Rugalema, 1992; Maruo, 2002; WAC, 2009; Zeleke, 2009; Akinnifesi *et al.*, 2010). The observation that the choice of species used in homegardens in the present study differs from one homegarden to another, agrees with the findings reported by (Munishi *et al.*, 2004).

Mixed intercropping is becoming an important practice for food and income earnings as supported by the findings by Mgeni (2008) and Kiptot and Franzel (2011). Woody perennials that are growing are of different types, aiming to provide nutrients to crops, thereby improving farmers food security and income generation. Farmers have recognized the importance of mixed intercropping and its potential on livelihoods for the communities in the Arumeru District. The crops grown are used as the farmer's source of cash and food.

Boundary planting and livefence technologies are also preferred by the local communities in the study area because of the need to protect fields from encroachment by animals during the dry season, soil fertility improvement, protection from wind, income from the selling of the fruits and vegetables from the boundary and livefence trees. Similar observation was reported by Parwada *et al.* (2010) in Zimbabwe.

Fodder shrubs are grown along boundaries and pathways or in lines along the contours to form terraces, thus reducing erosion and providing firewood. Fodder can be cut and fed to cows and goats in stall feeding mechanisms as reported by Ajayi *et al.* (2006), Jamal *et al.* (2006), Franzel and Wambugu (2007), Parwada *et al.* (2010) and Kiptot and Franzel (2011). It helps to reduce the cost of animal feeds for smallholder farmers. Results from other studies similarly report the significance of fodder banks in meeting food and income requirements at household level (Sileshi *et al.*, 2007).

Households owning rotational woodlots in the study area are very few (i.e. 6%). This was due to the prevailing drought, lack of seeds and or seedlings and land shortage. From the rotational woodlots, farmers obtain different benefits for domestic uses and income generation, all of which contribute to the improvement of livelihoods of the local people (Akinnifesi *et al.*, 2008; Onyango *et al.*, 2010; Oyebade *et al.*, 2010; Kiptot and Franzel, 2011). Rotational woodlots have great promise of reducing deforestation as well as increasing crop production in the district. The same reported by Otsyina *et al.* (1996), Nyadz (2002), TAFORI (2004), Kimaro *et al.* (2007) and Maduka (2007).

Alley farming as an agroforestry technology in the study area was also practiced by a small proportion (i.e. 3%) of the respondents. Alley farming aims at maintaining soil fertility, increasing crop yields and to provide a sustainable alternative to shifting agriculture (Quandt, 2010). The woody plants from the tree rows are regularly cut, leaves and twigs are used as mulch on the cropped alleys in order to reduce evaporation from the soil surface, suppress weeds and adding nutrients. The wood provides fuelwood and building poles, fruits and fodder (Beetz, 2002; Kimaro *et al.*, 2007; Lulandala, 2010). The agroforestry components forming the integration in the study area included herbaceous crops for food and income as well as livestock/pasture and various indigenous and exotic tree species (Appendices 20 and 21).

### 5.3 Extent of Agroforestry Contribution to Household Food Security and Income Generation of the Local Communities in Arumeru District

The results on the contribution of various sources of household food security of local communities in Arumeru District is presented in Table 7 with the details in Appendix 23. On the average, agroforestry had the highest contribution to household food security as compared to other sources. The contribution of agroforestry to food security is both direct

and indirect as it provides direct food products and through the sale of agroforestry products to generate income which in turn could be used to purchase food. The same reported by Paul (2011) and Fernandes *et al.* (1984). The environmental protective role of trees and/or shrubs enhance water and soil conservation in order to maintain high levels of production. This observation is supported by findings by Edward (2003) and Paul (2011).

Other studies (Regmi, 2003; Kebebew and Urgessa, 2011) reported high contribution of agroforestry to household food security. Businesses, were also important contributors to food security in Arumeru District, in conformity with the findings of (BCIS, 2012). Because of the high population and land fragmentation, most of the land in Arumeru District is under agroforestry homegardens management. Agriculture, which is said to be the mainstay of this countrys' economy (Myaka *et al.*, 2003), accounts for only 5% of the food security of the people in this district. The inability experienced by farmers in obtaining inputs such as fertilizers and their associated higher prices force them to abandon agricultural practices and shift to agroforestry practices (Kaukab and Chakravartii, 2011). Monde *et al.* (2008) however, reported that agriculture as a local economic activity, was preferred by the households but its contribution to their food needs was very low. The low contribution of livestock to household food supply has been observed in different studies (Shalli, 2003). This is especially a serious problem in the drier lower agro ecological zone of the district which have inadequate pasture and water during the dry periods when water and pasture become scarce. The same reported by USAID (2009). However, livestock sector plays an important role in the cultural and social situations of the farmers. The low role played by the forestry sector in influencing the local communities in this mainly agroforestry area, are in correspondence with those observed elsewhere (Akinnifesi *et al.*, 2006; Mtuya, 2006; Hill, 2007; Sileshi *et al.*, 2008; Oyebede *et al.*, 2010). This is because most of the products the forestry sector provides for

community livelihoods such as fruits, medicinal products, mushrooms, honey, caterpillars, flying termites and bush meat for the household are fully catered for in agroforestry practices Makonda and Gillah (2007), Sileshi *et al.* (2007) and Kalaba *et al.* (2010).

The results on the contribution of various sources of household income generation of local communities in Arumeru District is presented in Table 8 with the details in Appendix 24. Agroforestry has the highest contribution to the household income generation, followed by agriculture and employment. A study by Kebebew and Urgessa (2011) reported highest contribution of agroforestry to the income generation. This means that sometimes households purchase food items to attain food security and the high purchasing power of households is due to income generated from agroforestry. Agriculture, which is also an important source of income in the district, accounts for only 4% of the income generated. The level of importance of agriculture in sustaining livelihoods been reported by Myaka *et al.* (2003). The importance of employment as a contributor to the income generation of the local communities of Arumeru District had similarly been reported earlier by BCIS (2012).

### 5.4 Various Factors Influencing the Adoption of Agroforestry and Measures Required for Improvement

The results in Table 9 with the raw data and statistical detail in Appendices 25 and 26 respectively, show the different factors that enhance the contribution of agroforestry to household food security and income livelihoods of the communities in Arumeru District thereby promoting the adoption of its various systems and technologies. Most of the villages in the study area have good roads which are reported to support the marketing of agroforestry products. The same findings were reported by Mgeni (2008). Parwada *et al.*

(2010) similarly reported communication networks to significantly influence the adoption of agroforestry.

Important of soil fertility through addition of animal manure, especially for farmers practicing agrosilvopastoral system in the present study promote agroforestry adoption. Livestock and woody perennials are the sources of organic fertilizers for the crops, thus, they have great influence on agroforestry adoption. Farmers reported that when trees are integrated with crops, they have ability of improving soil fertility and soil structure, and hence increased crop productivity. These results correspond well with those findings reported by Oyebede *et al.* (2010). Foliage trimmings from trees/shrubs in the boundary and other agroforestry technologies, provide organic fertilizers to the soils.

Most of the villages in the study area are close to Arusha Municipal where the farmers sell their products to town dwellers and are therefore assured of markets. In fact households are practicing agroforestry because of the demand of their diverse products to their customers in the city. The observation that farmers got higher prices for their farm produce, agrees with findings reported earlier (WAC, 2009; Kaukab and Chakravartii, 2011). Some of the most common products sold include milk, eggs, vegetables and fruits which have high values in the town markets. Markets and marketing infrastructure in Arumeru District play an important role in enhancing the adoption of agroforestry, the observation which concurs with the findings reported by and Kashuliza *et al.* (2002), Wiskerke (2008) and WAC (2009). With access to market information, farmers make informed decisions about the needs of their customers when planning what to produce at the various periods (Wiskerke, 2008; Kiptot and Franzel, 2011).

The need for fodder was also observed to be one of the critically important factors promoting agroforestry adoption in the district. Farmers have recognized its importance and potential requirement for promoting milk production. These findings have been reported by Regmi (2003), Jamal *et al.* (2006), Chirwa *et al.* (2008) and Quandt (2010). Deforestation in the area of study created inadequacies in fuelwood availability. Therefore, adoption of agroforestry ensured fuelwood availability at the household level as has been reported by Ham and Theron (2010), and Kiptot and Franzel (2011). A household with a small piece of land in Arumeru District was motivated to practice agroforestry to have multiple products. With population increase, more food production and income generation are required in the district as observed by Musotsi *et al.* (2008) and Parwada *et al.* (2010).

Education for a district dwellers is an important tool for enhancing agroforestry adoption. This has been reported by Buyinza and Wambede (2008), and Quandt (2010). Some households practice agroforestry because of the education given freely by present organizations in the district, namely, FTI and RECODA. Training of farmer in nursery establishment in order to increase seedling outputs, agrees with the findings reported earlier by Akinnifesi *et al.* (2006). Through the use of available irrigation water, farmers cultivate bananas and coffee together with tomatoes, vegetables, onions, beans and maize, the products which have high market values. The same results were supported earlier by Ffolliott (2005) and Monde *et al.* (2008). Households in the district adopted have agroforestry because they knew that trees produce much needed timber for local house construction; poles and timber for sale for income generation to buy alternative materials for house constructions, an aspect which was well related by findings reported by Ham and Theron (2010), and Quandt (2010). Some of the households in the Arumeru District adopted agroforestry systems through inheritance and by buying land with agroforestry

structures. Similar findings were reported by O'Kting'ati and Mongi (1996) for Kilimanjaro Region.

The results in Table 10 with the raw data and statistical details in Appendices 27 and 28 respectively, show factors that were found to be limiting the adoption of agroforestry in Arumeru District. Decreases in precipitation affected negatively agroforestry adoption in the district. Similar findings have been reported by Mtuya (2006) and Quandt (2010). Also, climate change across the tropics and sub-tropics have been reported to have the same effect on crop production in general (Parwada *et al.*, 2010; vanStraaten *et al.*, 2010).

Poor understanding of agroforestry systems dynamics been reported to have negative influence on agroforestry adoption (Buyinza *et al.*, 2008; Buyinza and Wambede, 2008; Parwada *et al.*, 2010; Quandt, 2010). Thus, farmers should be empowered with knowledge for effective implementation of agroforestry. Findings of Kalaba *et al.* (2010) and WAC (2009) agree with the current findings.

Some households reported diseases and pests to be among the factors hindering productivity of agroforestry practices in Arumeru District. Chicken production was threatened by deadly diseases locally called as New Castle Disease. Due to poverty, farmers control diseases using non effective local means, as a result end up losing their livestock and crops. Irshad *et al.* (2011) reported the same situation in Pakistan. Prevalance of diseases affecting crops and livestock has been reported by Lulandala (2010) and Parwada *et al.* (2010).

Lack of seeds and or seedlings was one of the factors that limited the adoption of agroforestry in the district as was previously observed by Mtuya (2006), WAC (2009), and

Parwada *et al.* (2010 ). Regmi (2003) and SWF (2005) reported the negative impacts of the lack of planting materials and their information to agroforestry practices.

Livestock keepers reported to graze their cattle in crop fields during the dry season when agricultural crops have been harvested, in order to browse on the trees, the situation which reduce the sustainability of agroforestry practices. Other people invade agroforestry farms and cut down trees/ shrubs and grasses without permission of the owners, the aspect which is in conformity with the findings reported elsewhere (Mtuya, 2006; Ham and Theron, 2010). During this study, it was observed that open areas and communal lands were already overgrazed.

Lack of financial inputs in livestock and crop production, hindered the adoption of agroforestry in the study area. The results are also, supported by findings by Nair (1984), Bonifasi (2004) and Monde *et al.* (2008). High production costs in agroforestry practices are reported to be due to high transaction costs (Ssemwaga *et al.*, 2004), Rahim *et al.* (2005). The negative effect of land shortage on farmers adopting agroforestry had similarly been observed by Cook and Michael (1991), Nair (1993), Armele (1995), Alavalapati *et al.* (1995), MNRT (2003), and Ajayi *et al.* (2007) for various locations.

The results on measures required for improving the adoption of agroforestry and its contribution to household food security and income generation in the district are presented in Table 11 with raw data and statistical analysis in Appendices 29 and 30 respectively. These include the improvement in transportation networks, availability of water for irrigation and livestock especially during dry season, and secure markets for various agroforestry products, provision of knowledge to the communities, planting materials, credit facilities, legislations and formation of bylaws. Besides the provision of water for

irrigation and livestock, most of these measures are available through the effective extension services (Kashuliza *et al.*, 2002; Bukenya *et al.*, 2007; Mgeni, 2008; WAC, 2009). Agroforestry extension services will ensure better use of the limited renewable natural resources in the district and ineffective resource conservation (Irwin, 1997; Sonoko, 2001; Buyinza *et al.*, 2008; Shilabu, 2008) and in the procurement and production of tree seeds and seedlings (Regmi, 2003; SWF, 2005; Mtuya, 2006) and various other germplasms (Kiwale, 2002). Credit would prop-up the process in production, transportation and marketing various agroforestry products (Diagne, 1998; Ham and Theron, 2010; BCIS, 2012). As observed by Kashuliza *et al.* (2002), legislation and bylaws take into account the various aspects including protection of agroforestry practices from various sources of harm and regulation of prices of the agroforestry products.

# CHAPTER SIX

## 6.0 CONCLUSIONS AND RECOMMENDATIONS

### 6.1 Conclusions

Based on the results and discussion, the following conclusions have been reached:-

The main sources of food security and income generation to the households of the Arumeru District's community are agroforestry, business, agriculture, forestry, employment, honey, relatives, livestock and VICOBA. Agroforestry was the main source of households food security and income generation followed by businesses.

Agroforestry systems practiced in the study area included agrosilvopasture, agrosilviculture, silvopasture, aposilviculture, agroaquosilvopasture and agroaposilvopasture systems. The most widely used agroforestry system in the district was agrosilvopasture, followed by agrosilviculture and silvopasture.

Agroforestry technologies adopted in the study area included; Mixed intercropping, boundary planting/livefence, fodder bank, homegarden, rotational woodlots and alley cropping. Of the agroforestry technologies, the homegardens were highly adopted followed by mixed intercropping and boundary planting/ livefence.

On average, agroforestry contributed highest to household food security of the community in the district followed by the businesses. Also, agroforestry was the highest contributor to the household income generation followed by agriculture and employment. Agroforestry contributed to environmental protection, enhancement of water and soil conservation and in maintaining high levels of systems productivity.

Good transportation network (roads) and soil fertility were the most important factors that promoted adoption of agroforestry in the district.

Drought and lack of knowledge were the most limiting factors in the adoption of agroforestry in the study area.

Provision of water for irrigation and extension services were indicated to be the most required measures in improving the performance of agroforestry practices in Arumeru District.

### 6.2 Recommendations

Based on the preceding discussion and conclusions the following recommendations have been reached:-

i Achieving the full benefits promised by agroforestry, the agroforestry research centers in Tanzania should put emphasis on the most preferred agroforestry systems and practices (Agrosilvopasture, Agrosilviculture, Silvopasture, homegarden, mixed intercropping and boundary planting/livefence) for better and higher production thus, sustained a total annual contribution to household food security and income generation in the district.

ii The present factors promoting agroforestry systems and technologies in the district should be given due attention so as to encourage them and support farmers to ensure their sustainability.

iii The government should facilitate the formation of farmer groups to disseminate knowledge and other services for farmers to improve sustainable production.

iv There is a need for the district to allocate adequate financial resources for the improvement of the working environment of extension staff and recruitment of staff in the forest field, at ward and village levels to strengthen agroforestry extension, so as to attain food security and income generation at household level.

Arumeru farmers should adopt the drought resistant crops and trees/shrubs and, also, request for water services during the dry season.

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# APPENDICES

## Appendix 1: Household questionnaire

### A: Background information

| | |
|---|---|
| 1. Name of interviewee | |
| 2. Household number | |
| 3. Village | |
| 4. Ward. | |
| 5. Division | |
| 6. Name of interviewer<br>7. Date of interview | |

### B: Socio-economic factors and characteristic of dwelling.

1. Sex of respondent ..... 01 Male 02 Female

2. Age of respondent ----------

3. Marital status 01 Married 02 Single 03 Divorced 04 Widowed

4. Ability to read or write ..... 01Yes 02 No

5. If yes, what is the highest level of education attained? 01Informal schooling (Adult education 02 Primary education 03 Secondary education 04 College 05 Others *(specify)* ----------

6. Number of years in school ----------

7. Family size----------

8. Occupation of respondent----------

9. Do you own land? 01 Yes 02 No

10 If yes, what is your land size? ----------

11. How did you acquire your land? 01 Inherited 02 Bought 03 Hiring 04 Others *(Specify)* ----------

**C: Agroforestry systems and practices adopted by farmers**

1. Do you plant trees on your agricultural farm? 1 Yes 2 No
2. If yes, what are the reasons to plant trees on your farm? *(Tick appropriate responses)*

| | | | | | |
|---|---|---|---|---|---|
| Firewood | 1 | Windbreak | 6 | Income generation | 11 |
| Construction poles | 2 | Boundary demarcation | 7 | Medicine | 12 |
| Timber | 3 | Fencing | 8 | Hobbies | 13 |
| Shade | 4 | Fruits | 9 | Other *(specify)* ------ | 14 |
| Fodder | 5 | Beautification | 10 | | |

If no, give reasons ----------

3. What agroforestry systems does the farmer implement? *(Tick appropriate)*

| | |
|---|---|
| Trees + Crops | 1 |
| Trees + Animals | 2 |
| Trees + Aquatic life forms | 3 |
| Trees + Bees | 4 |
| Trees + Crops + Animals | 5 |

4. What types of agroforestry practices are adopted by the farmer? *(Tick appropriate)*

| | | | |
|---|---|---|---|
| Alley cropping | 1 | Woodlot | 6 |
| Live fencing | 2 | Fodder bank | 7 |
| Boundary planting | 3 | Home garden | 8 |
| Dispersed tree in cropland | 4 | Others *(specify)* ----- | 9 |
| Improved fallow | 5 | | |

5. What tree species are commonly preferred by farmers in Agroforestry systems? -----

**D: Sources of Household Food Security and Income**

**Crop component**

1 What are the sources of your family food? 1 On-farm 2 Off-farm 3 Both

2. What are the sources of your household income? 1 On-farm 2 Off-farm 3 Both

3. Specify types of crops grown, quantities produced and their equivalent market prices as the contribution of the crop component to household food security and income generation per year.

| **Type of crop** | **Total production in (Bags , Tins)** | **Amount stoked for food** | | **Amount sold for household income** | |
|---|---|---|---|---|---|
| | | **Amount in ( Bags, Tins)** | **TSH** | **Amount in (Bags, Tins)** | **TSH** |
| Maize | | | | | |
| Sorghum | | | | | |
| Cassava | | | | | |
| Sunflower | | | | | |
| Sweet potatoes | | | | | |
| Beans | | | | | |
| Irish potatoes | | | | | |
| Banana | | | | | |
| Tomatoes | | | | | |
| Sugar cane | | | | | |
| Papaya | | | | | |
| Guava | | | | | |
| Vegetables | | | | | |
| Others *(Specify)*----- | | | | | |

3. Who takes care for the crops planted with trees on the same field? 1 Father 2 Mother 3 Children 4 Whole family
4. Who makes decisions on the use of money earned from selling of different crops? 1 Father 2 Mother 3 Children 4 Whole family

**Animal component**

5. Does the farmer sell his/her livestock as supplement strategies to household food security and income generation? 1 Yes 2 No
6. Who takes care for the livestock? 1 Father 2 Mother 3 Children 4 Whole family
7. Who makes decisions on the use of money earned from selling of livestock/livestock products? 1 Father 2 Mother 3 Children 4 Whole family

8. Specify types of livestock or livestock products sold, quantities and their equivalent market prices as the contribution of the animal component to household food security and income generation per year.

| **Type of livestock** | **Total Quantity** | **Quantity sold** | **The total amount of money earned** | **Amount spends for food** | **The amount used for supporting of household expenditures** |
|---|---|---|---|---|---|
| Cattle | | | | | |
| Sheep | | | | | |
| Goat | | | | | |
| Donkey | | | | | |
| Pigs | | | | | |
| Chicken | | | | | |
| Ducks | | | | | |
| Eggs | | | | | |
| Milk | | | | | |
| Hides | | | | | |
| Others *(specify)* -- | | | | | |

**Tree component**

9. Do you sell your tree/tree products planted in the same field with crops? 1 Yes 2 No

10. Who takes care for trees planted in the cropland? 1 Father 2 Mother 3 Children 4 Whole family

11. Who makes decisions on the use of money earned from selling of tree products?

1 Father 2 Mother 3 Children 4 Whole family

12. Where do you sell your tree products? 1 neighbor 2 Local market 3 Industrialists

4. Others *(specify)* ----------

13. Specify type forest products sold, quantities and their equivalent market prices as the contribution of a tree component to household food security and income generation per year.

| **Type of tree products sold** | **Unit of measure** | **Total quantity** | **The total amount of money earned** | **Amount spends for food** | **The amount used for supporting of household expenditures** |
|---|---|---|---|---|---|
| Fuelwood | | | | | |
| Fruits | | | | | |
| Charcoal | | | | | |
| Timber | | | | | |
| Poles | | | | | |
| Honey | | | | | |
| Ropes | | | | | |
| Withiers | | | | | |
| Medicine | | | | | |
| Nuts | | | | | |
| Oil | | | | | |
| Others *(Specify)*--- | | | | | |

**Contribution of off -farm activities to household food security and income**

14. Apart from agroforestry, do you have any other sources of household income?

1. Yes 2. No

15. If yes, who performs most of the off-farm works? Father 2 Mother 3 Children 4 Whole family

16. Who makes decisions on the use of money generated from off-farm sources?

1 Father 2 Mother 3 Children 4 Whole family

17. Specify the contribution of off-farm activities to household food security and income generation per year.

| **Off-farm sources** | **Total amount of money earned per year** | **Amount spend for food** | **Amount used for supporting of household expenditures** |
|---|---|---|---|
| Local brew | | | |
| Casual labour | | | |
| Formal employment | | | |
| Remittances | | | |
| Business | | | |

**E: Factors hindering scaling-up of Agroforestry and measures to improve their performances**

1. Do you think growing trees and crops in the same land assist you to get your basic family needs? 1 Yes 2 No
2. Do you face any problem on the course of growing trees and crops on the same land? 1 Yes 2 No
3. If yes, what problems do you face? .....
4. Arumeru District is one of the potential areas for agroforestry. What factors enhance agroforestry activities in Arusha District? ----------
5. What measure do you think should be taken in order to improve agroforestry activities in Arusha District? ----------

**Farmers' training and agroforestry extension services**

1. Where do you get seed/seedlings? 1 Own sources 2 Buying from street vendors 3 buying from District council 4 Given free from District Council 5 Given by neighbours 6 Others (specify)----------
2. Have you attended any training in agroforestry? 1 Yes 2 No
3. If yes, who organized the training?----------
4. What did you learnt? ----------

## Appendix 2. CHECKLIST OF PROBE QUESTIONS FOR THE KEY INFORMANTS

1. What are the common on-farm sources of household income?
2. What are the common off-farm sources of household income?
3. What are the sources of food for your household?
4. Why do you practice agroforestry?
5. What agroforestry systems are commonly adopted by farmers? Give reasons for their choice?
6. What agroforestry practices are commonly adopted by farmers? Give reasons for their choice?
7. What types of trees do you prefer to plant in agroforestry systems?
8. Where do you get firewood for your household consumption?
9. What problems do face on planting trees and crops on the same field?
10. What should be done in order to improve agroforestry activities in your village?

**THANK YOU.**

**Appendix 3: Frequencies for the various sources household food security of the local communities in Arumeru District in general**

| Source | Lower zone | Medium | Upper | Mean |
|---|---|---|---|---|
| Agroforestry | 40 | 40 | 40 | 40.0 |
| Business | 7 | 3 | 3 | 4.3 |
| Agriculture | 5 | 4 | 2 | 3.7 |
| Employment | 4 | 1 | 0 | 1.7 |
| Honey | 4 | 0 | 1 | 1.7 |
| Livestock | 1 | 3 | 0 | 1.3 |
| Forest | 1 | 4 | 0 | 1.7 |
| VICOBA | 0 | 2 | 0 | 0.7 |
| Relatives | 0 | 1 | 4 | 1.7 |

**Appendix 4: ANOVA for the various sources household food security of local communities in Arumeru District**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Sources/treatments | 8 | 3866.296296 | 483.287037 | 157.69 | 0.0001 |
| Zone/replications | 2 | 8.296296 | 4.148148 | 1.35 | 0.2864 |
| Error | 16 | 49.037037 | 3.064815 | | |
| Total | 26 | 3923.629630 | | | |

Least Significant Difference (LSD) = 3.0302

**Appendix 5: Frequencies for the various sources of household income for the local communities in Arumeru District**

| Source | Lower | Medium | Upper | Mean |
|---|---|---|---|---|
| Agroforestry | 40 | 39 | 40 | 39.7 |
| Business | 13 | 10 | 10 | 11.0 |
| Employment | 7 | 4 | 6 | 5.7 |
| Agriculture | 5 | 4 | 2 | 3.7 |
| Livestock | 3 | 3 | 0 | 2.0 |
| Honey | 3 | 0 | 2 | 1.7 |
| Forest | 0 | 3 | 0 | 1.0 |
| VICOBA | 0 | 2 | 0 | 0.7 |
| Relatives | 0 | 1 | 4 | 1.7 |

**Appendix 6: ANOVA for the various sources of household income of local communities of Arumeru District**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Sources/treatments | 8 | 3756.666667 | 469.583333 | 182.76 | <.0001 |
| Zone/replications | 2 | 2.888889 | 1.444444 | 0.56 | 0.5808 |
| Error | 16 | 41.111111 | 2.569444 | | |
| Total | 26 | 3800.666667 | | | |

Least Significant Difference (LSD) = 2.7745

**Appendix 7: Frequencies for the various agroforestry systems adopted in Arumeru District**

| System | Lower | Medium | Upper | Means |
|---|---|---|---|---|
| Agrosilvopasture | 36 | 34 | 36 | 35.3 |
| Agrosilviculture | 4 | 3 | 6 | 4.3 |
| Silvopasture | 2 | 5 | 1 | 2.7 |
| Aposilviculture | 2 | 1 | 1 | 1.3 |
| Agroaquosilvopasture | 0 | 2 | 1 | 1.0 |
| Agroaposilvopasture | 2 | 0 | 0 | 0.7 |

**Appendix 8: ANOVA for the various agroforestry systems in use in Arumeru District**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Systems/treatments | 5 | 2805.111111 | 561.022222 | 264.36 | 0.0001 |
| Zones/replications | 2 | 0.111111 | 0.055556 | 0.03 | 0.9742 |
| Error | 10 | 21.222222 | 2.122222 | | |
| Total | 17 | 2826.444444 | | | |

Least Significant Difference (LSD) = 2.6503

**Appendix 9: Frequencies for the various agroforestry systems adopted in the lower agro ecological zone of Arumeru District**

| System | Mbuguni ward | Nduruma ward | Means |
|---|---|---|---|
| Agrosilvopasture | 19 | 17 | 18 |
| Agrosilviculture | 1 | 3 | 2 |
| Silvopasture | 1 | 1 | 1 |
| Aposilviculture | 1 | 1 | 1 |
| Agroaposilvopasture | 1 | 1 | 1 |

**Appendix 10: ANOVA table for the various agroforestry systems adopted in the lower agro-ecological zone of Arumeru District**

| Source | DF | SS | MS | F Value | P |
|---|---|---|---|---|---|
| Systems/treatments | 4 | 450.4000000 | 112.6000000 | 112.60 | 0.0002 |
| Ward/replication | 1 | 0.0000000 | 0.0000000 | 0.00 | 1.0000 |
| Error | 4 | 4.0000000 | 1.0000000 | | |
| Total | 9 | 454.4000000 | | | |

Least Significant Difference (LSD) = 2.7764

**Appendix 11: Frequencies for the various agroforestry systems adopted in the medium agro ecological zone of Arumeru District**

| System | Maroroni ward | Matevesi ward | Means |
|---|---|---|---|
| Agrosilvopasture | 20 | 14 | 17.0 |
| Aposilviculture | 1 | 0 | 0.5 |
| Agrosilviculture | 0 | 3 | 1.5 |
| Silvopasture | 0 | 5 | 2.5 |
| Agroaposilvopasture | 0 | 2 | 1.0 |

**Appendix 12: ANOVA table for the various agroforestry systems adopted in the medium agro ecological zone of Arumeru District**

| Source | DF | SS | MS | F Value | P |
|---|---|---|---|---|---|
| Systems/treatments | 4 | 395.0000000 | 98.7500000 | 10.79 | 0.0204 |
| Ward/replication | 1 | 0.9000000 | 0.9000000 | 0.10 | 0.7695 |
| Error | 4 | 36.6000000 | 9.1500000 | | |
| Total | 9 | 432.5000000 | | | |

Least Significant Difference (LSD) = 8.3985

**Appendix 13: Frequencies for the various agroforestry systems adopted in the Upper agro ecological zone of Arumeru District**

| System | Sambasha ward | Polising'isi ward | Means |
|---|---|---|---|
| Agrosilvopasture | 17 | 19 | 18 |
| Agrosilviculture | 5 | 1 | 3 |
| Agroaposilvopasture | 1 | 0 | 0.5 |
| Silvopasture | 0 | 1 | 0.5 |
| Aposilviculture | 0 | 1 | 0.5 |

**Appendix 14: The ANOVA table for the various agroforestry systems adopted in the upper agro ecological zone of Arumeru District**

| Source | DF | SS | MS | F Value | P |
|---|---|---|---|---|---|
| Systems/treatments | 4 | 465.0000000 | 116.2500000 | 40.79 | 0.0017 |
| Ward/replication | 1 | 0.1000000 | 0.1000000 | 0.04 | 0.8605 |
| Error | 4 | 11.4000000 | 2.8500000 | | |
| Total | 9 | 476.5000000 | | | |

Least Significant Difference (LSD) = 4.6872

**Appendix 15: Frequencies for the various agroforestry technologies in use in Arumeru District**

| Technology | Lower | Medium | Upper | Means |
|---|---|---|---|---|
| Mixed intercropping | 39 | 19 | 15 | 24.3 |
| Boundary and/or live fence | 14 | 5 | 29 | 16.0 |
| Rotational woodlot | 6 | 3 | 6 | 5.0 |
| Homegarden | 6 | 33 | 40 | 26.3 |
| Alley cropping | 4 | 1 | 2 | 2.3 |
| Fodder bank | 3 | 1 | 15 | 6.4 |

**Appendix 16: ANOVA for the various agroforestry technologies in use in Arumeru District**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Technologies/treatments | 5 | 2664.944444 | 532.988889 | 34.79 | 0.0001 |
| Zones/replications | 2 | 186.111111 | 93.055556 | 6.07 | 0.0188 |
| Error | 10 | 153.222222 | 15.322222 | | |
| Total | 17 | 3004.277778 | | | |

Least Significant Difference (LSD) = 7.1213

**Appendix 17: Frequencies for the various agroforestry technologies adopted in the lower agro-ecological zone of Arumeru District**

| Technology | Mbuguni ward | Nduruma ward | Means |
|---|---|---|---|
| Intercropping | 19 | 20 | 19.5 |
| Boundary and/or live fence | 4 | 10 | 7 |
| Homegarden | 4 | 2 | 3 |
| Rotational woodlot | 3 | 3 | 3 |
| Alley cropping | 1 | 3 | 2 |
| Fodder bank | 1 | 2 | 1.5 |

**Appendix 18: ANOVA table for the various agroforestry technologies adopted in lower agro-ecological zone Arumeru District**

| Source | DF | SS | MS | F Value | P |
|---|---|---|---|---|---|
| Technologies/treatments | 5 | 475.0000000 | 95.0000000 | 26.89 | 0.0013 |
| Ward/replication | 1 | 5.3333333 | 5.3333333 | 1.51 | 0.2739 |
| Error | 5 | 17.6666667 | 3.5333333 | | |
| Total | 11 | 498.0000000 | | | |

Least Significant Difference (LSD) = 4.832

**Appendix 19: Frequencies for the various agroforestry technologies adopted in the Medium agro-ecological zone of Arumeru District**

| Technology | Maroroni ward | Matevesi ward | Means |
|---|---|---|---|
| Intercropping | 10 | 9 | 9.5 |
| Boundary /live fence | 2 | 3 | 2.5 |
| Fodder bank | 1 | 0 | 0.5 |
| Alley cropping | 1 | 0 | 0.5 |
| Woodlot | 1 | 2 | 1.5 |
| Homegarden | 18 | 15 | 16.5 |

**Appendix 20: ANOVA table for the various agroforestry technologies adopted in medium agro-ecological zone Arumeru District**

| Source | DF | SS | MS | F Value | P |
|---|---|---|---|---|---|
| Technologies/treatments | 5 | 422.6666667 | 84.5333333 | 39.62 | 0.0005 |
| Ward/replication | 1 | 0.3333333 | 0.3333333 | 0.16 | 0.7089 |
| Error | 5 | 10.6666667 | 2.1333333 | | |
| Total | 11 | 433.6666667 | | | |

Least Significant Difference (LSD) = 3.7546

**Appendix 21: Frequencies for the various agroforestry technologies adopted in the upper agro-ecological zone of Arumeru District**

| Technology | Sambasha ward | Polising'isi ward | Means |
|---|---|---|---|
| Homegarden | 20 | 20 | 20 |
| Boundary/ livefence | 19 | 10 | 14.5 |
| Intercropping | 7 | 8 | 7.5 |
| Fodder bank | 6 | 9 | 7.5 |
| Alley cropping | 1 | 1 | 1 |
| Woodlot | 1 | 5 | 3 |

**Appendix 22: ANOVA table for the various agroforestry technologies adopted in upper agro-ecological zone Arumeru District**

| Source | DF | SS | MS | F Value | P |
|---|---|---|---|---|---|
| Technologies/treatments | 5 | 511.4166667 | 102.2833333 | 9.57 | 0.0135 |
| Ward/replication | 1 | 0.0833333 | 0.0833333 | 0.01 | 0.9331 |
| Error | 5 | 53.4166667 | 10.6833333 | | |
| Total | 11 | 564.9166667 | | | |

Least Significant Difference (LSD) = 8.402

**Appendix 23: Contribution of various sources to household food security for the local communities in Arumeru District**

| Source | | Quantinty | Price | Average Income (Tshs/hh/yr | Average | % |
|---|---|---|---|---|---|---|
| Agroforestry | Maize | 120.12bg | 25,000 | 3,003,000 | 1,124,940 | 88.6 |
| | Beans | 69.81bag | 28,200 | 1,968,642 | | |
| | Livestock | - | 938,362 | 938,362 | | |
| | Tree | - | 476,484 | 476,484 | | |
| | Beekeeping | - | 8,000 | 1,460,800 | | |
| | Fruits | 182.6L | 1,500 | 15,780 | | |
| | Fish | 10.5bags | 11,509 | 11,509 | | |
| | Sub-Total | - | | 7,874,577 | | |
| Business | Kiosk | - | | 148,898 | 64,754 | 5.1 |
| | Mamalishe | - | | 100,647 | | |
| | Flour milling | | | 73,749 | | |
| | Petty trade | | | 59,754 | | |
| | Retail shop | | | 32,377 | | |
| | Bodaboda&bajaji | | | 30,758 | | |
| | Traditional doctors | | | 7,094 | | |
| | Sub-Total | | | 453,277 | | |
| | | | | | 46,978 | 3.7 |
| Agriculture | Maize | 6.8bags | 25,000 | 170,051 | | |
| | Beans | 1.5bags | 28,200 | 42,200 | | |
| | Potatoes | | | 13,740 | | |
| | Vegetables | | | 8,899 | | |
| | Sub-total | | | 234,890 | | |
| Livestock | | | | 17,776 | 17,776 | 1.4 |
| VICOBA | | | | 5,079 | 5,079 | 0.4 |
| Relatives | | | | 3,809 | 3,809 | 0.3 |
| | Civil service | | | 4,539 | | |
| Employment | Private&NGOs | | | 3,078 | | |
| | Casual labour | | | 2,000 | | |
| | Sub-Total | | | 9,617 | 2,539 | 0.2 |
| Forest | Firewood | | | 1,270 | 1,270 | 0.1 |
| **Total** | | | | 8,598,295 | 1,269,684 | 100 |

**Appendix 24: Contribution of various sources to household income for the local communities in Arumeru District**

| Source | | Average Quantity | Average Price | Average Income (Tshs/hh/yr | Average | Percentage |
|---|---|---|---|---|---|---|
| Agroforestry | Honey | 112.5 Lt | 8,000 | 900,000 | | |
| | Firewood | 51headload | 2,000 | 102,000 | | |
| | Charcoal | | 8,000 | 54,400 | | |
| | Maize | 6.8bags | 25,000 | 100,800 | | |
| | Beans | 4.032bags | 28,200 | 95,880 | | |
| | Livestock | 3.4bags | - | 1,952,827 | | |
| | Tree | - | 384,045 | 1,152,135 | 654,353 | 84.3 |
| | Vegetable | 3pieces | - | 25,801 | | |
| | Fishes | - | - | 10,000 | | |
| | Pol&Timber | - | - | 1,800,240 | | |
| | Banana | - | 18,000 | 144,000 | | |
| | Fruits | 8pieces | 1,500 | 22,500 | | |
| | | 15bags | Sub-Total | 6,360,583 | | |
| Agriculture | Maize | 2bags | 25,000 | 50,000 | 34,154 | 4.4 |
| | Beans | 1.5bag | 28,200 | 18,308 | | |
| | | | Sub-total | 68,308 | | |
| Employment | Civil service | 12month | 3,968.42 | 47,621 | 31,049 | 4.0 |
| | Private&NGOs | 12month | | 29,997 | | |
| | Casual labour | 12month | 2,499.75 | 15,525 | | |
| | | | | 93,143 | | |
| | | | Sub-Total | | | |
| Business | Petty trade | | | 28,080 | 28,720 | 3.7 |
| | Retail shop | | | 50,900 | | |
| | Millingmashi | | | 26,620 | | |
| | Tailor | | | 21,540 | | |
| | Kiosk | | | 33,080 | | |
| | Bodaboda&bajaji | | | 12,100 | | |
| | | | Sub-Total | 172,320 | | |
| Livestock | - | - | - | 18,629 | 18,629 | 2.4 |
| Relatives | - | - | - | 3,881 | 3,881 | 0.5 |
| VICOBA | - | - | - | 3,881 | 3,881 | 0.5 |
| Forestry | Firewood | 0.78headLoad | 2000 | 1,552 | 1,552 | 0.2 |
| | | | **Total** | **4,942,185** | **776,219** | **100** |

**Appendix 25: Frequencies for the factors promoting the adoption of agroforestry in Arumeru District**

| Factors | Agro-ecological zone | | | |
|---|---|---|---|---|
| | Lower | Medium | Upper | Mean |
| Transportation networks | 15 | 14 | 10 | 13.0 |
| Soil fertility | 7 | 4 | 9 | 6.7 |
| Fodder need | 6 | 5 | 6 | 5.7 |
| Water for irrigation | 6 | 0 | 0 | 2.0 |
| Education | 5 | 0 | 1 | 2.0 |
| Market availability | 4 | 5 | 9 | 6.0 |
| Land scarcity | 3 | 1 | 4 | 2.7 |
| Construction materials | 1 | 1 | 1 | 1.0 |
| Firewood | 1 | 0 | 5 | 2.0 |
| Population increase | 0 | 2 | 4 | 2.0 |
| Its a custom | 0 | 0 | 3 | 1.0 |

**Appendix 26: ANOVA for the factors promoting the adoption of agroforestry i Arumeru District**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Factors/treatments | 10 | 392.0000000 | 39.2000000 | 8.56 | 0.0001 |
| Zones/replications | 2 | 20.3636364 | 10.1818182 | 2.22 | 0.1344 |
| Error | 20 | 91.6363636 | 4.5818182 | | |
| Total | 32 | 504.0000000 | | | |

Least Significant Difference (LSD) = 3.6457

**Appendix 27: Frequencies for the various factors limiting the adoption of agroforestry in Arumeru District**

| Factors limiting | Zone | | | |
|---|---|---|---|---|
| | Lower | Medium | Upper | Mean |
| Drought | 24 | 20 | 20 | 21.3 |
| Knowledge | 16 | 16 | 6 | 12.7 |
| Disease | 3 | 8 | 0 | 3.7 |
| Seedling | 1 | 9 | 0 | 3.3 |
| Animal | 4 | 3 | 1 | 2.7 |
| Financial constraints | 0 | 5 | 2 | 2.3 |
| Land scarcity | 1 | 1 | 1 | 1.0 |

**Appendix 28: ANOVA for the various factors limiting the adoption of agroforestry in Arumeru District**

| Source | DF | SS | MS | F | P-value |
|---|---|---|---|---|---|
| Factors/treatments | 6 | 1014.285714 | 169.047619 | 19.89 | 0.0001 |
| Zones/replications | 2 | 74.000000 | 37.000000 | 4.35 | 0.0379 |
| Error | 12 | 102.000000 | 8.500000 | | |
| Total | 20 | 1190.285714 | | | |

Least Significant Difference (LSD) = 5.1866

**Appendix 29: Frequencies for the measures required for improvement of agroforestry in Arumeru District.**

| Measure | Zones | | | |
|---|---|---|---|---|
| | Lower | Medium | Upper | Mean |
| Water for irrigation | 3 | 1 | 1 | 1.7 |
| Extension services | 18 | 2 | 6 | 8.7 |
| Involvement of NGO's on knowledge provision | 6 | 0 | 7 | 4.3 |
| Provision of seed/seedling | 35 | 6 | 19 | 20.0 |
| Market for agroforestry products | 12 | 0 | 3 | 5.0 |
| Input on time | 11 | 2 | 3 | 5.3 |
| Capital | 5 | 0 | 4 | 3.0 |
| Land provision | 30 | 1 | 1 | 10.7 |
| Transportation network (i.e. roads) | 3 | 1 | 4 | 2.7 |
| Abolition of free grazing | 4 | 1 | 2 | 2.3 |
| Farm credit | 15 | 1 | 2 | 6.0 |

**Appendix 30: ANOVA for the measures required for improvement of agroforestry adoption in Arumeru District.**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Factors/treatments | 10 | 840.6666667 | 84.0666667 | 2.59 | 0.0336 |
| Zones/replications | 2 | 775.6969697 | 387.8484848 | 11.95 | 0.0004 |
| Error | 20 | 648.969697 | 32.448485 | | |
| Total | 32 | 2265.333333 | | | |

Least Significant Difference (LSD) = 9.7019

## Appendix 31: Frequencies for the tree species adopted in Arumeru District

| Species | Lower | Medium | Upper zone | Mean |
|---|---|---|---|---|
| *Rauvolfia caffra* | 10 | 8 | 16 | 11.3 |
| *Gravillea robusta* | 18 | 14 | 34 | 22.0 |
| *Prunus persica* | 0 | 0 | 7 | 2.3 |
| *Mangifera indica* | 27 | 11 | 22 | 20.0 |
| *Perse Americana* | 8 | 4 | 27 | 13 0 |
| *Cordia Africana* | 15 | 6 | 18 | 13.0 |
| *Croton macrostachyus* | 6 | 7 | 22 | 11.7 |
| *Jacaranda mimosifolia* | 3 | 3 | 11 | 5 7 |
| *Casualina spp.* | 1 | 0 | 3 | 1 3 |
| *Senna spectabilis* | 0 | 3 | 7 | 3.3 |
| *Leucaena cephaloceae* | 6 | 10 | 8 | 8.0 |
| *Senna siamea* | 20 | 30 | 19 | 23.0 |
| *Calliandra calothyrsus* | 0 | 0 | 4 | 1.3 |
| *Coffea Arabica* | 0 | 0 | 9 | 3.0 |
| *Makharnia lutea* | 9 | 13 | 5 | 9.0 |
| *Acacia spp.* | 20 | 23 | 2 | 15.0 |
| *Albizia gunifera* | 3 | 3 | 15 | 7.0 |
| *Cupressus lusitanica* | 0 | 0 | 2 | 0.7 |
| *Carica papaya* | 3 | 0 | 4 | 2.3 |
| *Olea europaea var. Africana* | 6 | 5 | 13 | 8.0 |
| *Psidium guajava* | 5 | 6 | 5 | 5.3 |
| *Passiflora edulis* | 0 | 0 | 1 | 0.3 |
| *Artocarpus heterophyllus* | 2 | 2 | 0 | 1.3 |
| *Azadirachta indica* | 11 | 9 | 2 | 7.3 |
| *Euphobia tirucalii* | 3 | 20 | 4 | 9.0 |
| *Sterculia appendiculata* | 5 | 8 | 1 | 4.7 |
| *Olea capensis* | 0 | 1 | 0 | 0.3 |
| *Tamarindus indica* | 5 | 1 | 0 | 2.0 |
| *Commiphora Africana* | 0 | 6 | 0 | 2.0 |
| *Grewia bicolor* | 0 | 5 | 0 | 1.7 |
| *Ziziphus mucronata* | 0 | 3 | 0 | 1.0 |
| *Erythrina abyssinica* | 0 | 1 | 0 | 0.3 |
| *Grewia villosa* | 1 | 0 | 0 | 0.3 |
| *Balanite aegyptiaca* | 0 | 12 | 0 | 4.0 |
| *Acacia xanthophloea* | 2 | 5 | 0 | 2.3 |
| *Schinus molle* | 4 | 7 | 0 | 3.7 |
| *Ficus thonningii* | 3 | 6 | 0 | 3.0 |
| *Annona senegalensis* | 5 | 5 | 1 | 3.7 |
| *Pithecellobium dulce* | 4 | 3 | 0 | 2.3 |
| *Delonix regia* | 2 | 1 | 0 | 1.0 |
| *Combretum molle* | 1 | 0 | 7 | 2.7 |
| *Acacia nilotica* | 2 | 10 | 0 | 4.0 |

**Appendix 32: ANOVA for the tree species adopted in Arumeru District**

| Source | DF | SS | MS | F | P |
|---|---|---|---|---|---|
| Species/treatments | 41 | 4325.301587 | 105.495161 | 4.02 | 0.0001 |
| Zones/replications | 2 | 43.539683 | 21.769841 | 0.83 | 0.4399 |
| Error | 82 | 2151.793651 | 26.241386 | | |
| Total | 125 | 6520.634921 | | | |

Least Significant Difference (LSD) = 8.3206