ADDIS ABABA UNIVERSITY

SCHOOL OF GRADUATE STUDIES

ALTERNATIVE TECHNOLOGIES FOR SUSTAINABLE AGRICULTURAL PRODUCTION AND AGROECOSYSTEM CONSERVATION IN ARSI HIGHLANDS, SOUTHEASTERN ETHIOPIA

BY

BERHANU MENGESHA

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Berhanu Mengesha

A Thesis Submitted to the School of Graduate Studies of Addis Ababa University in Partial Fulfilment of the Requirements for the Degree of Doctor of Philosophy in Botanical Sciences

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DEDICATION

This thesis is dedicated to the Ethiopian Farmers who have lived under persistent poverty for centuries.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

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ABSTRACT

Alternative technologies for sustainable agricultural production and ecosystem conservation study were conducted in Arsi Zone, Oromia Region. A total of 180 sample households were selected from 12 kebeles (smallest administrative unit in Ethiopia) of four weredas (districts). The households were stratified into rich, medium and poor wealth groups based on local criteria. Biophysical and socioeconomic data were collected using semi-structured interviews, Focus Group Discussions (FGDs) and interviews of key informants. Data on socioeconomics, agricultural crops and tree and shrub species were organized and analysed using computer software: SPSS, EXCEL and PAST. The diversity and composition of crop, tree and shrub species and agricultural crop production were characterized and the factors that affect their dynamics were identified. A total of 44 agricultural crop species were recorded of which *Triticum aestivum*, *Hordeum vulgare, Eragrostis tef* and *Zea mays* were the most common crops. In addition, a total of 90 tree and shrub species were recorded, among which, *Juniperus procera, Olea europaea* subsp. *cuspidata, Podocarpus falcatus, Acacia tortilis, Acacia etbaica* and *Hagenia abyssinica* were the main indigneous and multipurpose tree species. *Eucalyptus globulus* occurred in most of the farms (63%) and was the most important exotic tree species with highest relative values as fuelwood (35.6), construction (37.8), windbreak (22.2), income generation (30.0) and conservation (13.3). There were differences in averge annual incomes of the households among the rich (Birr 13,712), medium (Birr 9,148) and poor (Birr 5967) wealth groups. The main factors which were identified to create differences among the wealth groups were: landholding, family size, livestock resources, agricultural crop and tree and shrub species diversity and income sources in all weredas. The rich had more average landholding, number of livestock and use mix of organic and inorganic fertilizers than the medium wealth group households and the medium wealth group had more average landholding, number of livestock and use mix of organic and inorganic fertilizers than the poor households. Thus, the uses of diversified and low agricultural inputs technologies have effect on the improvements of the livelihoods of the local communities. To ensure sustainable agricultural production and agroecosystem conservation, it is concluded that the country‘s educational, research and extension systems have much work ahead to support extension workers, farmers and policy makers in order to adequately deal with complex local farming systems that have co-evolved with human societies to fit local ecological conditions and satisfy human needs.

Key words: Agroecological approach, biodiversity, diversification, ecosystem

1. INTRODUCTION

Agriculture is formally defined as the science, art or practice of cultivating the soil, producing crops and raising livestock and in varying degrees, the preparation and marketing of the resulting products (Heitschmidt *et al,* 2004). Agriculture is the single largest component of global land use, with some 36% of the world‘s land surface devoted to providing the primary produce needed to sustain people. Agriculture contributes 24% of global GDP and provides employment to 1.3 billion people (Wei *et al*., 2009). The unchecked pursuit of economic growth through industrialization forces rural dwellers to overexploit natural resources as a means of paying for the basic requisites, once freely available in the community. Forests are being cut and burned, grasslands are being overgrazed and natural plant communities are being cleared for agricultural purposes. Also, crops are being over-watered, air and water are polluted, and fertilizers, herbicides and pesticides are being applied in excessive doses (Mika, 2004; Odada *et al*, 2009).

Agricultural activity and its enhancement to cater for the needs of growing human populations have led to the remodeling of natural landscapes in many countries (New, 2001; Odada, 2009). Extensive conversion of forests and agricultural intensification are typically identified as the most prominent drivers of land-use changes, which have the largest global impact on biodiversity, followed by climate change, nitrogen deposition and changing concentration of atmospheric CO_2 (Mosquera-Losada *et al*., 2009). Also, boosting food production through commercially intensive agriculture and livestock rearing creates a loss of community‘s knowledge, culture and traditional livelihoods (Balick and Cox, 1996). Rampant growth diminishes the capacity of the rural areas to provide essential services, as cropland is degraded through massive inputs of fertilizers and pesticides. Water for irrigation purposes is combined with these chemical flows and contaminates rivers in both rural and urban areas.

The reports of Mosquera-Losada *et al*. (2009), Wei *et al*. (2009), and Odada *et al*. (2009) have shown that the management of agroecosystems and evaluation has been heavily dependent on human values, the economic and social components, which caused malfunctioning of agroecosystems like land degradation, emission of greenhouse gases, loss of biodiversity, nitrate leaching to water bodies and depletion of groundwater. Conversion of natural ecosystems to agricultural production often accelerates soil erosion, acidification - primarily as a consequence of base depletion from crop removal, increased organic matter decomposition and the application of ammonium-based nitrogen fertilizers (McCool *et al*., 2001; Khan and Nafees, 2002). This shows that the agricultural production has been improved through the modernization of agriculture, but has adverse environmental and social impacts (Khan and Nafees, 2002).

Ethiopia‘s agricultural sector is a major contributor to the economy and central to food security and poverty reduction. Agriculture accounts for an estimated 44% of national gross domestic product (GDP), about 86% of export and 80% of employment (Word Bank, 2009). The same report showed that nearly 90% of the poor depend on agriculture for their livelihood. However, due to lack of sustainable use of the natural resources, land degradation, poverty and food insecurity are pervasive and interconnected problems in Ethiopia (Holden and Bekele Shiferaw, 2004). Environmental degradation is persistent and extreme and natural resources deterioration is so serious. Soil degradation studies made in the 1980s and 1990s have shown that around 52% of the highlands of Ethiopia were affected by various degrees of soil degradation, half of which were described as very critical (Solomon Abate, 1994). From these studies, some have estimated 10 billion metric tons of soil was lost per year during the 1970s (Myers, 1986) leading to around 30 percent of Ethiopia's agricultural land being degraded by 1990 (Hutchinson *et al*., 1991). In the highlands, annual topsoil loss depth was estimated from two to ten centimeters per year (Mohammad Abbi, 1995). Some analysts estimated that countries in the Greater Horn of Africa could be losing more than 20 kilograms of nitrogen, 8 kilograms of phosphorus, and more than 20 kilograms of potassium per hectare per year (van Reuler and Prins, 1993). If the current process of soil degradation is allowed to continue at the present rate, one-third to one-half of the total area of the Ethiopian highlands will be completely unsuitable for crop production at some point in the next two decades (Solomon Abate, 1994). Also, some studies have suggested that if the current environmental degradation is permitted to continue, human settlement in many parts of the country could become unsustainable (Hutchinson *et al*., 1991).

According to Patil *et al*. (2001), understanding the relationships that exist between ecosystems and socioeconomic systems across time and space is essential to design economic, environmental and natural resource policies that aspire to achieve sustainable outcomes with high levels of ecosystem health and quality of human life. The search for answers to many of the problems of conservation and sustainable development associated with rural people in developing countries requires a more holistic and participatory approach to research than has conventionally been the case. Research approaches need to correspond more closely to the multi-dimensional realities of people‘s lives. Understanding of relationships between the botanical, ecological, social, economic and political dimensions are very essential for managing plant resources and conserving botanical diversity (Hamilton *et al*., 2003; Odada *et al.*, 2009). The concept of agricultural sustainability has emerged in response to concerns about the adverse environmental and economic impacts of conventional agriculture (Rasul and Thapa, 2003).

Arsi Zone is located on the south-eastern mountain massifs of the country, which are ecologically sensitive to human interventions and also having great potentials in the provision of different ecological, economical, and social benefits. However, most parts of the Arsi highlands are devoid of vegetation and highly degraded due to increasing pressure on land for agricultural expansion and non-sustainable use of natural resources. Loss of soil fertility due to high rate of soil erosion, leaching of nutrients, removal of crop residues and cow-dung and low inherent soil fertility has threatened productivity of the zone. Uses of modern agricultural technologies, which include agrochemicals and improved seeds, have enabled some farmers to improve their production. However, the ever-increasing cost of these agricultural inputs and their inherent effects on the micro-organisms of the soil and environmental pollution, production could not be sustainable. Sustainable agricultural production and ecosystem conservation requires careful design based on detailed scientific knowledge. Poverty, malnutrition, low crop and livestock productivity and resource degradation are major problems in rural Ethiopia. These problems are highly interrelated and reinforce one another and have kept the rural population in a state of vicious cycle of underdevelopment and environmental degradation. Therefore, looking for alternative technologies, which are economically feasible, environment friendly and socially acceptable are essential.

The purpose of this study was, therefore, to assess and identify agricultural practices in Arsi highlands, which are ecologically sound, economically viable and socially acceptable. In addition, the aim was to identify the technology that reintegrates the traditional agriculture knowledge and adds new ecological knowledge into the intensification process, which can contribute towards meeting these challenges. This approach offers an alternative path to agricultural intensification by relying on local farming knowledge and techniques adjusted to different local conditions, management of diverse on-fram resources and inputs, and incorporation of contemporary scientific understanding of biological principles and resources in farming systems.

2. LITERATURE REVIEW

2.1. Historical Development of Agriculture

Early humans depended on hunting, fishing and food gathering. It is thought that humankind went through a three phase development. However, as various groups of people undertook deliberate cultivation of wild plants and domestication of wild animals, agriculture came into being (Balick and Cox, 1996; Alemayehu Assefa, 2003; Vyas, 2006). Early agricultural implements like digging stick, hoe, scythe and plough developed slowly over the centuries, and each innovation caused profound changes in human life. From early time too, humans created indigenous systems of irrigation especially in semi-arid areas and regions with long period of dry seasons. In the 16th and 17th centuries, horticulture was greatly developed and contributed to agricultural revolution. The industrial revolution, after the late 18th century, increased the population of towns and cities and increasingly forced agriculture into greater integration with general economic and financial patterns (Vyas, 2006). The era of mechanized agriculture began with the invention of such farm machines as the reaper, cultivator, thresher, combiner and tractor, which continued to appear over the years leading to a new type of large scale agriculture.

There have been dramatic changes in agricultural production in many parts of the world over recent centuries and decades. Some of these followed the opening up of the world by European exploration and colonization from about 1500, for example, with maize and potato being introduced into the Old World, and wheat and sugarcane into the Americas (Cunningham, 2001). Science has become a major force for change over the last 150 years, during which time advances in chemistry and biology, including genetics and plant physiology, have led to significant developments in soil science, crop-breeding and pest-control. The last 50 years, in particular, have seen a major intensification of agriculture in some regions, involving the introduction of high yielding varieties of crops, much use of agricultural machinery and major increases in inputs of water, chemical fertilizers, pesticides and fossil energy. Such agriculture is referred to as ‗intensive‘, though ironically it is often called ‗conventional‘ by agriculturists (Hamilton *et al*., 2003).

However, throughout the world, wild, naturalized or non-cultivated plants still provide low cost building materials, fuel, food supplements, herbal medicines, basketry containers for storage, processing or preparation of food crops, or as a source of income. Edible wild foods often help prevent starvation during drought, while economically important species provide a buffer against unemployment during cyclical economic depressions (Cunningham, 2001). According to Altieri (1995), about 60 percent of the world‘s cultivated land is still farmed by traditional and subsistence methods. The traditional use of biologically diverse resources not only reflects a varied resource-use pattern, but also variety in the methods of maintaining biological diversity in ecosystems. Many of these agroecosystems are small-scale, geographically discontinuous, and located on a multitude of slopes, aspects, microclimate, elevation zones, and soil types. In many areas, traditional farmers have developed and/or inherited complex systems, adapted to the local conditions helping them to sustainably manage harsh environments and to meet their subsistence needs, without depending on mechanization, chemical fertilizers, pesticides or other technologies of modern agricultural science (Altieri, 2000). On the other hand, there is tremendous pressure on the farming communities to change their ways of living, ecological knowledge and cultural practices that have been continuously developed and transferred from generation to generation are being lost (Altieri, 1995; Altieri, 2000; Hamilton *et al*., 2003).

More than ever before in human history, the way in which land is being used has become a source of wide spread concern. The population of the world exceeds six billion; hence, the demand for accessible and safe food is higher than ever, while the negative impacts of food production on the quality of the natural resources are increasingly recognized (Van Keulen, 2007). Over the past 50 years, human beings have changed natural ecosystems more rapidly and extensively than in any comparable period of time in human history, largely to meet rapidly growing demands for food, fresh water, timber, fiber and fuel (Green Facts, 2005; Vyas, 2006). Increases in agricultural productivity have, come in part, at the expense of deterioration of the natural resources base on which farming systems depend (Fischer, 2002). Deforestation, loss of the germplasm of traditional crops and extinction of plant and animal species have threatened the production of quality and quantity of food and raw materials for the subsistence farmers (Sentis, 1992; Villarroel Coca, 2002; Vyas, 2006). At the same time, globalization leads to increasing pressure on the economic viability of food production systems, resulting in a search for more rewarding land uses by farmers, in both the developed and developing world and the eventual abandonment of land (Van Keulen, 2007).

Environmentally, there are many problems with intensive agriculture, such as worries concerning its massive use of water, energy and chemicals, and its side effects of loss of soil fertility and structure, soil erosion, damage to human health, and pollution. Since 1970, the worldwide rate of application of nitrogen fertilizers has increased by seven times (Martin, 1995; Cunningham, 2001; Hamilton et al., 2003) where half to two-thirds of nitrogen fertilizers now enter non-agricultural ecosystems with serious consequences for terrestrial, freshwater and marine ecology. Also, under conventional agriculture, humans have simplified the structure of the environment over vast areas, replacing natural diversity with a small number of cultivated plants and domesticated animals (Buck *et al*., 2004). This artificial ecosystem needs constant human intervention in planting site preparation, planting, and use of agrochemicals to control weed and different pests and manipulation of crop genetics (Altieri, 1995).

2.2. Contribution of Agriculture to the Economy

Agriculture provides the great bulk of food supporting people on Earth. Despite a very high percentage of terrestrial primary production being devoted to this cause, 700–800 million people still lack adequate access to food. It is not hard to predict that demands for food will rise sharply, because the size of the human population itself is predicted to grow from its present six billion to 9 billion in 2050 (World Bank 2006). There is considerable disagreement about how best to meet this challenge, a problem compounded by the likelihood of considerable environmental uncertainty, for example due to climatic change. The area under cultivation could expand by 20-40% by 2020 (Hamilton *et al*., 2003). Agriculture is a key cruise of the global economy. It supports the livelihoods and subsistence of the largest number of people worldwide and is vital to rural development and poverty alleviation, as well as food and non-food production. The main challenge for the agricultural sector are to simultaneously: i) secure enough high quality agricultural production to meet demand, ii) conserve biodiversity and manage natural resources sustainabily, and iii) improve human health and well-being, especially for the rural poor in developing countries.

Agriculture is the mainstay of the Ethiopian economy and of the people at large. Agriculture directly supports about 85% of the population (NMSA, 2001; Devi *et al.*, 2007). In terms of employment and livelihood, it contributes about 50% to the country‘s gross domestic product (GDP), source of 90% of the export earnings, and supplies around 70% of the raw material requirements of agro-based domestic industries and major source of food for the population of the nation (NMSA, 2001). The agricultural sector is based on smallholder farming which accounts for more than 90% of the agricultural production and 95% of the total area under crops. Smallholder farmers produce 94% of cereals and 98% of coffee (Belaineh Legesse, 2003). The role of the smallholder is thus, very significant and they have overwhelming importance in the agricultural sector and economic progress of the country in the production of food, creation of job, and foreign exchange earnings. In addition, agriculture is expected to play a key role in generating surplus capital to speed up the overall socio-economic development of the country. About 73.6 million hectares (66%) of the country‘s land area is estimated to be potentially suitable for agricultural production. Out of this arable land, about 16.5 million hectares (14.8% of the country) is under cultivation, most of which (about 88%) is covered by annual crops and the remaining being under perennial crops (NMSA, 2001).

Ethiopia has been faced with food deficits over the last several decades. Some studies show that about 50-years ago, Ethiopia had been an exporter of grains and legumes estimated on an average of 90,000 tons to its East African and Arabian Peninsula neighbors (Howard *et al.*, 1995) whereas it has become increasingly dependent on supplies of donated food aid in recent years. Different types of farming systems are practiced in the various agroecological zones of which the major types include mixed farming, large scale commercial farming and pastoral system (MoA, 1995; Devi *et al.*, 2007). Peasant farmers inhabiting the highlands and mid-highlands predominantly practice mixed farming system; the large scale commercial farms are mostly operated by the state and private investors in the highlands and mid-highland zones while the pastoral production is common in the lowland areas.

Ethiopia contains unique lowland and highland centers of endemism, which have a great importance to global biodiversity. These are being degraded and lost as rural populations become more desperate to sustain their livelihoods. Significant progress in poverty reduction in the country will depend to a large extent on the ability to achieve growth in the agricultural sector – a major contributor to the economy and, hence, on attaining sustainable land management (SLM). The anthropogenic causes of land degradation are multiple and complex, which is largely attributable to the abuse and overexploitation of the natural resource base, particularly through inappropriate and unsustainable agricultural policies and practices, forest degradation and complication derived from natural disasters.

According to Holden *et al*. (2005), most of Ethiopia‘s population lives in the highlands, where land degradation and droughts threaten food security. Soil erosion in Ethiopia averages nearly 10 times the rate of soil regeneration, and the country has among the highest estimated rates of soil nutrient depletion in Sub-Saharan Africa. Such land degradation reduces average agricultural productivity. It also increases farmers‘ vulnerability to drought by reducing soil depth and moisture–holding capacity. The combined effects of low productivity and ecosystem degradation lock the poor in a vicious cycle of poverty and environmental degradation. However, soil erosion continues unabated and nearly 50% of the soils of the country have been significantly eroded and 25% seriously eroded (Alemneh Dejene, 2004).

2.3. Factors Affecting Agricultural Ecosystems

According to Xu and Mage (2001), agroecosystems are designed and managed primarily for providing food, fibre and other agricultural products for human uses. These authors have made detailed reviews on the criteria of assessing agroecosystem health based on four major characterstics, namely structural, functional, organizational and dynamics. Land, water, climate and vegetation are constituents of agoecosystems which are used by farmers in agricultural production (Altieri, 1995). The productivity of these resources depends on physical, chemical, biological and social components of the agroecosystem which include topography, soil depth, surface water availability, average rainfall, temperature, natural vegetation and existing social and political setup. Agroecosystems also provide clean water, regulate carbon, nutrient cycling or soil maintenance, and are equally important to sustaining agricultural ecosystems.

Long-term sustainable development of agriculture ranges from the maintenance of a supportive biophysical resource base, the economic viability of production, and the continuation of a sufficient supply of agricultural products, to the social vitality of agriculture-based rural communities (Xu and Mage, 2001). The health of an agricultural ecosystem depends on the way the land is used, the quality of the soil and the input and output of the nutrients (WBCD, 2008). Conversion of natural ecosystems to agricultural production often accelerates soil erosion, acidification, primarily as a consequence of base depletion from crop removal, increased organic matter decomposition, and the application of ammonium-based nitrogen fertilizers (McCool *et al.,* 2001). Tillage-based farming systems also exploit organic matter and quickly exhaust biologically oxidizable forms. Soil biology is vital to the functioning of soil, and thus can influence the sustainability of an agroecosystem. Tillage alters the physical and chemical characteristics of the soil, and this will profoundly affect the growth, functioning and survival of the soil biota.

Maintaining soil quality is very important for sustainable production, which can be influenced by the contents of organic matter, fertility, physical properties and microbial process (Vance, 2000). Soil degradation is a major environmental problem worldwide and there is strong indication that the soil degradation processes cause an immediate threat to both biomass and economic yields of agriculture, as well as a long-term risk to future crop yield (Pagliai *et al*., 2004). Reduction in soil structure degradation is one of the main aims of land management to minimize the impact of agricultural activities on the environment. An important component of sustainable land management is the management of soil and plant nutrients. Soil fertility can be improved by managing nutrient stocks, organic matter content and flows (Vance, 2000). Plant nutrients are usually removed from the crop and forest systems through harvests of grain, tubers, and wood also by surface erosion and subsurface leaching. Loss of soil fertility due to high rate of soil erosion, leaching of nutrients, removal of crop residues and cow-dung and low inherent soil fertility has threatened wide areas of Sub-Saharan African countries of which Ethiopia is a part (Tesfaye Teklay, 2005). This has exacerbated the depletion of nutrients, which have limiting effect on plant growth and crop production.

Sustainable production of crops, livestock and wood products depend on systems of land use that maintain soil fertility and reduce erosion and other kinds of degradation (World Bank, 2006). Land use and land cover changes in Ethiopia are extremely complex because of human interactions that are determined by a whole range of factors. Where there is intense population pressure, sustainable land use development concerns are often critical. Especially, in the highlands of the country, intense land use activities have often resulted in land degradation, declining water tables and soil fertility related problems. The problems associated with high magnitudes of erosion in the Ethiopian highlands are caused by a combination of erosive rains, steep slopes and human impact by deforestation and agricultural systems (Nyssen *et al.,* 2004). Living at subsistence or below subsistence level economies, it becomes imperative not to ignore sustainable livelihood concerns of these rural communities in the short run and sustainable development needs of the country as a long term strategy, while dealing with the ecological and social processes determining land use dynamics.

In the Ethiopian highlands, population pressure pushed cultivation and livestock grazing to steep slopes and fragile lands causing serious devegetation and soil erosion, while about 12 million ha of Vertisols remained under utilized because of poor internal drainage and resultant flooding and water logging during the rainy season (Mohammad Abbi, 1995). Also, soil fertility is declining because manure is principally used as fuel and chemical fertilizers are expensive. Efforts to improve soil fertility include livestock production, efficient use of crop residue and manure and introduction of herbaceous, tree forage legumes that can fix atmospheric nitrogen (Mohammad Abbi, 1995).

The capacity of land to maintain the present levels of food production may be jeopardized by the erosion of the natural resource base, leading to a deterioration of the food security in the agricultural ecosystem. Existing studies suggest widespread loss of productive potential due to intensive use of soil types that are highly sensitive to erosion and nutrient depletion, or those that are inherently low in nutrients or organic matter. Therefore, encouraging farmers to adopt more sustainable methods of farming that will have long-term benefits in environmental conservation and development of sustainable livelihood is essential. Sustainable natural resources management include: improving agroecosystem productivity, conserving biodiversity, reducing land degradation, improving water management and ensuring the sustainabile management of forests.

2.4. Agricultural Land Management

According to Jackson *et al*. (2007), 10% of the global land area is under modern intensive agricultural use, 17% is under extensive use associated with the use of far fewer artificial inputs, and 40% is grazed by domesticated livesock. The report also showed that by 2050, food production must be double to meet human needs. The challenge facing agriculture over the coming decades will be an expanding global economy to achieve stable production on a sustainable basis by introducing technologies and management practices that would ensure a healthy environment, stable production, economic efficiency and equitable sharing of social benefits (Heywood 1996). This also requires to identify specific agricultural and rural development needs and opportunities, and to focus investment in areas where the greatest impact on food insecurity and poverty will be achieved. This identification and resource allocation process can be facilitated by analyzing farming systems in order to develop an understanding of local factors and linkages.

The combined effects of biomass shortages, soil and land degradation, overgrazing and increasing populations are hindering the success of sustainable agricultural systems in the Ethiopian highlands (Jagger and Pender, 2000). Clearance of vegetation has also exposed the soil to wind and water erosion of which Ethiopia has one of the highest rates of soil nutrient depletion in Sub-Saharan Africa (Pender *et al*., 2001). Land degradation contributes to low agricultural productivity (Amare Haileslassie *et al.,* 2007), extreme poverty and food insecurity, as evidenced by recurrent problems of famine and incomes of less than one dollar per person per day.

Due to loss of plant cover and use of agricultural residues for different purposes, natural nutrient recycling have been broken down. Deforestation has caused change in climate and loss of organic material in the soil which has diminished the efficiency and effectiveness of take-up of the agricultural chemicals by plants. The farmers have high cost of production and suffer in the decline of productivity. The adoption of more efficient farming practices and technologies that enhance agricultural productivity and improve environmental sustainability is instrumental for achieving economic growth, food security and poverty alleviation in the country.

Agricultural production, including food and livestock husbandry, is determined by the interaction of farmers with natural resources, traditional practices, government policies and environmental fluctuations. These interactions result in farming systems. According to Koutsouris (2008), a farming system can be defined as a combination of elements in recognizable proportions, which, over a predetermined period, produces identifiable agricultural products of an anticipated standard in anticipated quantities. Each individual farm has its own specific characteristics arising from variations in resource endowments and family circumstances. Local farming systems are complex adaptive systems that have co-evolved with human societies to fit local ecological conditions and satisfy human needs. The household, its resources, and the resource flows and interactions at this individual farm level are together referred to as a farm system (FAO, 1991). Farming systems are determined both by the natural landscape and the prevailing socio-economic conditions of the area (Sentis, 1992). Therefore, the biophysical, socio-economic and human elements of a farm are independent and, thus, farms can be analyzed as systems from various points of view.

The delineation of the major farming systems provides a useful framework within which appropriate agricultural development strategies and interventions can be determined. The decision to adopt very broad farming systems inevitably results in a considerable degree of heterogeneity within any single system. However, the alternative of identifying numerous, discrete, micro-level farming systems would complicate the interpretation of appropriate strategic responses and detract from the overall impact of the analysis. Only the major farming systems have, therefore, been identified. According to FAO (1991), there are eight broad categories of farming systems based on the following criteria:

(a) available natural resource base, including water, land, grazing areas and forest; climate of which altitude is one important determinant; landscape, including slope; farm size, tenure and organization; and

(b) dominant pattern of farm activities and household livelihoods, including field crops, livestock, trees, aquaculture, hunting and gathering, processing and off-farm activities; and taking into account the main technologies used, which determine the intensity of production and integration of crops, livestock and other activities.

The above criteria and broad grouping of farming systems were applied with a view to drawing conclusions with regard to poverty reduction and agricultural growth. The names also reflect key distinguishing attributes, notable: i) water resource availability, e.g. irrigated, rain fed, moist, dry; ii) climate, e.g. tropical, temperate, cold; iii) landscape relief/altitude, e.g. highland, lowland; iv) farm size, e.g. smaller or large scale; v) production intensity, e.g. intensive, extensive, sparse; vi) dominant livelihood source, e.g. root crop, maize, tree crop, artisanal fishing, pastoral; vii) dual crop livelihoods, e.g. cereal-root, rice-wheat (note that crop-livestock integration is denoted by the term mixed); and viii) location, e.g. forest based, coastal and urban based.

To ensure the sustainability of agricultural production and ecosystem conservation, agricultural land management requires the meeting of ecological, economical and social needs of the communities. This can be achieved through balanced environments, sustained yields, biologically mediated soil fertility and natural pest regulation through the design of diversified agroecosystems and the use of low-input technologies (Gleissman, 1998). Various strategies, which are considered useful to restore agricultural diversity are presented in the following sub-sections.

2.4.1. Diversity and productivity of agricultural crops

A common feature among smallholder farms of Sub-Saharan Africa (SSA) is the large heterogeneity in crop growth that can be observed within their relatively small area (Tittonell *et al*., 2007). The cultivation of different crops is regarded as a strategy of farmers to diversify their subsistence and cash needs (Mulatu Geleta *et al*., 2002; Tesfaye Abebe, 2005). Combining herbs and crops with trees also enhance nutrient recycling and reduce hazards of leaching and soil erosion (Tesfaye Abebe, 2005). Diversification also helps to stabilize yield or income in cases of incidence of disease and pest, and market price fluctuations. The variations in the natural environment and the farming systems functioning together under vigorous involvement of farming communities have created endemic crops and large number of local farmers‘ varieties (landraces); many of them genetically diverse and with distinctive adaptations (Mulatu Geleta *et al*., 2002).

Ethiopia has very diverse climatic conditions varying from hot and dry deserts in the lowland areas to cold and humid alpine habitats in highlands. Such diverse climatic conditions and habitats contributed to the presence of high species diversity in plants and animals, making Ethiopia one of the 25 mega diversity countries of the world in biodiversity (WCMC, 1992). The country takes a unique position in history of domestication of a wide range of crop categories including cereals, legumes, roots and tubers, stimulants, oils and other crops. Ethiopia is one of the twelve Vavilov Centers of crop diversity and main centers of origin/diversity for several cultivated crops and their wild weedy relatives (Mulatu Geleta *et al.*, 2002; IBC, 2005). Ethiopia has a very high genetic diversity in four of the world‘s widely grown food crops (wheat, barely, sorghum, and peas) (Benin *et al*., 2004), in three of the world‘s most important industrial crops (linseed, castor and cotton), in the world‘s most important cash crop (coffee) in a number of food crops of regional or local importance (TEF, finger millet, cowpeas, lentil, ENSET, etc.) and in a number of forage plants of world importance (clovers, lucerns, oats, etc.).

Ethiopia is considered the primary gene centre for field crops such as NOUG (*Guizotia abyssinica*), TEF (*Eragrostis tef*), and Ethiopian kale (*Brassica carinata*) and a secondary gene center for crops such as durum wheat, barely, sorghum, finger millet, linseed, sesame, safflower, faba bean, fieldpea, chickpea, lentil, cowpea, fenugreek and grasspea. Early introduced crops have developed wide ranges of genetic diversity under local ecological conditions and agricultural practices (Cunneyworth, 2001).

Agricultural biodiversity is decreasing world-wide due to the combined effects of specialisation, harmonisation and homogenisation all components of globalisation. People still convert traditional-type agricultural systems to lower agricultural biodiversity livelihood strategies due, amongst other causes, to prevailing economic distortions, which are institutionalised in the current global economic system, which include input subsidies, agricultural extension services, or widespread distribution of modern seeds in emergency relief package (Cromwell *et al.* 1997). Maintenance of and improved access to agricultural biodiversity can often contribute more to sustainable livelihoods than conversion, as their traditional entitlements to agricultural biodiversity may be stronger than their market access to agricultural production inputs. A salient feature of traditional farming systems is their degree of plant diversity in the form of polycultures and/or agroforestry patterns. These systems offer a means of promoting diversity of diet and income, stability of production, minimization of risk, reduced insect and disease incidence, efficient use of labor, intensification of production with limited resources, and maximization of returns under low levels of technology. The traditional Ethiopian farming systems and the diverse crops/landraces they maintained remained relatively stable for millennia (Mulatu Geleta *et al.*, 2002). It also conserves plant genetic resources while concurrently maintaining processes of evolution and adaptation in juxtaposition with indigenous knowledge.

According to Atlas of Arsi Zone (2004), the highland part of Arsi Zone is an intensively cultivated area because of good rainfall, moderate temperature, fertile volcanic soils and undualting to rolling plateau of its terrain. It is estimated that over 60% of the Arsi plateau is under cultivation. The cereals-based farming system in the

Arsi Zone is basically a mixed cropping system where different agricultural crops, including pulses and edible oil crops as well as domestic animals are integrated for the livelihoods of the subsistence farmers. The major food crops produced in the zone are cereals, pulses and oilcrops. It was reported in the Atlas that in the year 2000, cereal crops accounted for about 83 and 84% of total cultivated land and crop production, respectivily. Wheat (*Triticum eastivum*) is the the dominant agricultural crop grown in Arsi Zone covering the three main traditional agricultural landscapes of KOLA, WEYINA-DEGA and DEGA with high proprtion of cultivated land area.

2.4.2. Management of tree and shrub species diversity in the farming systems

Natural ecosystems can be useful as models for designing sustainable agricultural systems. The most conspicuous feature of natural forests is their multistoried organization of trees, shrubs, forbs and fungi, each using different levels of energy and resources and each contributing to the functioning of the entire systems (Farrell and Altieri, 1995; Nicholson *et al*., 2009). Ecosystem services include provisioning services (e.g. fresh water), regulating services (e.g. climate and flood regulation), cultural sevices (e.g. aesthetic and spiritual benefits) and supporting servces (e.g. nutrient cycling) (Nicholson *et al*., 2009). Forest layers lessen the mechanical impact of raindrops hitting the soil surface and reduce the amount of direct sunlight reaching the ground, thereby minimizing the potential for soil loss, reducing evaporation and slowing the rate of organic matter decomposition. On the soil surface, decaying plant litter provides a protective cover and a source of nutrients to be recycled. All these conditions create an ideal environment for microflora and fauna. Insects and earthworms promote the decay and incorporation of organic matter into the soil, creating good soil structure, which in turn enhance aeration, water filtration and cultural services (Farrell and Altieri, 1995).

The most critical environmental problems are deforestation, soil erosion and the decline in biological diversity (Kameri-Mbote and Cullet, 1999). Critical processes at the ecosystem level influence plant productivity, soil fertility, water quality, atmospheric chemistry, and many other local and global environmental conditions that ultimately affect human welfare. These ecosystem processes are controlled by the diversity and identity of the plant, animal and microbial species living within community (Naeem *et al*., 1999). Human modifications to the living community in an ecosystem - as well as to the collective biodiversity of the earth- can, therefore, alter ecological functions and life support services that are vital to the well-being of human societies.

With the recent publication of the Millennium Ecosystem Assessment, great optimism has been placed on the potential for biodiversity to supply ecosystem services, i.e., biophysical functions and ecological processes that support human life and welfare (Jackson *et al*., 2007). Where agriculture already dominates landscapes, the maintenance of biodiversity within these areas is an important component of total biodiversity conservation efforts, and, if managed appropriately, can also contribute to agricultural productivity and sustainability through the ecosystem services that biodiversity provides (such as through pest control, pollination, soil fertility, protection of water courses against soil erosion, and the removal of excessive nutrients (Brussaard *et al*., 2007; Jackson *et al*., 2007). Increased soil erosion and declining soil fertility are two major causes of reduced productive capacity, which are often not easily recognized, particularly in the short term (MacDicken and Vergara, 1990).

Trees may be intentionally planted or allowed to persist from natural regeneration in crop fields. A wide range of tree species are often grown with staple food crops in random or systematic spacing, often depending on the degree of reliance on natural regeneration and the type of tillage equipment used (MacDicken and Vergara, 1990). Integration of trees into agricultural systems may result in more efficient use of sunlight, moisture, and plant nutrients than is generally possible by monocropping of either agricultural crops or pure tree plantations. Combining trees with agricultural crops or livestock will achieve the objectives of sustainability, increased production and benefits to the rural poor.

Trees and shrubs are the very important components of the farming systems, which provide the local communities with wood products for domestic use and income generation, environmental protection, land productivity improvement, shelter and shade. Most of the present study sites were devoid of natural forests over the years and currently few patches of forests and scattered trees remain on the farms. Most of the local demands for forest products are met from trees planted in the homegarden and farm boundaries as well as woodlots.

The variation in species richness and density of trees in the different farming systems is related to ecological and socioeconomic conditions (Tesfaye Abebe, 2005). The level of household resources, such as landholding, is also expected to influence diversity and density of trees because resource poor farmers attach priority to subsistence crops for their survival. Arsi Zone is the first administrative area where modern agriculture was introduced in the beginning of 1970s. Introduction of modern agricultural inputs and mechanization have influenced traditional agricultural practices and forest area of the Zone.

2.4.3. Ethnobotany for sustainable agricultural production and ecosystem conservation

Ethnobiological knowledge and practices within any culture vary by geographical origin, residence, ethnicity, religion, occupation, educational background, social status and relation, income group, age and gender (Pfeiffer and Bultz, 2005). People throughout the tropics have depended on their indigenous plants for food security and a host of everyday products, from medicines to fibers. Plants have always been of central significance to human welfare and always will be. Plants provide people with food, fuel, medicines and materials for constructions and the manufacture of crafts and many other products (Hamilton *et al.,* 2003; Pfeiffer and Bultz, 2005). Their chemical and genetic constituents are being increasingly explored for human benefit. They are essential elements of ecological systems on all geographical scales, providing with equitable climates, fertile soils and reliable supplies of water. The central role of plants in the everyday lives of rural people is obvious in developing countries, with the daily round of activities revolving around agriculture, the care of domestic animals, the gathering of fuelwood, the cooking and eating of largely plant-based food, the construction of buildings and fences, the use of herbal medicine and so on (Balick and Cox, 1996; Hamilton *et al*., 2003).

With the ravage of deforestation, the overlooked indigenous plant resources have come under severe pressure, made worse by the growing numbers of people in tropical countries, many of whom depend upon these sources for fulfilling some of their basic needs. These pressures have led to the concept of domesticating many of these indigenous plants and incorporating them into agroforestry systems primarily for the benefit of small-scale, resource-poor farmers. This represents a new paradigm for feeding the world. Instead of focusing on a limited number of highly domesticated crops, often grown in monoculture, this new paradigm is based on a much greater diversity of plants, including many partially domesticated tree crops providing an array of products for consumption and trade. Understanding how local communities use and manage natural resources is essential for promoting conservation (Duchelle, 2007) of agricultural lands.

Ethnobotany can be applied for many practical purposes, in land-use-development, agriculture, forestry, cultural conservation, education and the development of the health, food and herbal medicine industries. Applied Ethnobotany draws on both personal (including traditional) and scientific forms of knowledge, allowing comparisons and integration for the benefits of conservation and sustainable development (Balick and Cox, 1996; Hamilton *et al*., 2003). Applied ethnobotany, a discipline, which is at the interface of social and biological sciences, is particularly useful in the context to analyze use, practices and perceptions as well as proposing new evenness for management (Aumeeruddy *et al*., 2004).

The traditional use of biologically-diverse resources not only reflects a varied resource-use pattern, but also variety in the methods of maintaining biological diversity in ecosystems. The relationship between plants and people are often clearer in indigenous societies than in present generation, since the link between production and consumption is more direct. Within a single village an ethnobotanist can study how people forage for wild plants or sow crops, how they use plants to construct houses, baskets, boats, or clothing, and the role plants play in myth and lore. In these cultures, such information resides within individuals, families, or villages. Indigenous cultures retain much knowledge concerning plants that Western peoples have largely lost (Balick and Cox, 1996).

Indigenous/local people have maintained knowledge of plant medicines, textiles, and plant cultivation strategies. Some knowledge, such as ethnotaxonomic systems (biological classification schemes used by indigenous people) or legends and myths concerning plant origins, are of interest because of the insight they shed on the cultures themselves. Indigenous/local peoples are stewards of some of the most sensitive ecosystems on this planet. Indigenous knowledge systems, developed over centuries of residence in such habitats, can inform current debate concerning the conservation of natural resources. In today‘s global economy, indigenous people are vulnerable to rapid economic and cultural change. Understanding of traditional ways, including uses of plants, can point to strategies for ameliorating negative consequences of that change.

However, there is tremendous pressure from socioeconomic change on ecological knowledge and cultural traditions that have been continuously developed and transferred from generation to generation. Participatory, community–based work to document, apply, and build on local knowledge of botanical resources and their management can help cope with such changes without losing valuable local knowledge and biodiversity. Therefore, ethnobotany applied to conservation and community development has become extremely important. The ideal ethnobotanist is a combination of an anthropologist, archaeologist, botanist, chemist, psychologist, ecologist, explorer, folklorist, pharmacologist and diplomat. Only through an interdisciplinary approach can we hope to understand the close connection between plants and human societies. Understanding of ethnobotanical studies of the country is limited to certain localities and use categories, for example, medicinal and edible plants (e.g., Mirutse Giday, 2007; Getachew Addis, 2009). By integrating indigenous knowledge and experience into local needs of the farming systems are more likely to be met in conservation of agroecosystem and land management decisions.

2.5. Agricultural Research and Extension Services in Ethiopia

The Ethiopian Agricultural Research Sector (EARS) has evolved through several stages since its first initiation during the late 1940s, following the establishment of agricultural and technical schools at Ambo and Jimma (Tesfaye Zegeye *et al*., 2004). The Imperial College of Agricultural and Mechanical Arts (now Haramaya University), with its Agricultural Experiment Station at Debre Zeit (now Debre Zeit Research Centre), was the major research entity until the mid 1960s. The establishment of the then Institute of Agricultural Research (IAR, now EIAR) in 1966 saw the first nationally coordinated agricultural research system in Ethiopia. According to Seme Debela (1987), the main objective for the establishment of the IAR was to foster the generation and dissemination of agricultural technologies that will help raise agricultural productivity and efficiency. The overall core functions of EIAR include: i) generating agricultural technologies and research capacity building, ii) popularization of improved technologies, iii) coordination of all agricultural research in the country, iv) advising Government on agricultural policy development, and v) networking and establishing partnerships with outside organizations (Tsedeke Abate, 2006). EARO (2003) has reported that 342 crop varieties have been released by the Ethiopian Agricultural Researches (EARS) during the period from 1970 to 2003, in addition to 49 improved technologies for livestock management, 45 for natural resources management, nine for agricultural engineering (farm implements) and five for forestry.

Although agricultural research in Ethiopia has produced several technologies for the last four decades, similar to extension activities, there is a clear feedback from the end users that many technologies developed by researchers‛ on-station were not adopted by farmers, which forced agricultural scientists and policy makers to re-examine their approaches and priorities. The major reason for non-adoption and poor dissemination of technologies was that past approaches, which were non-participatory and discipline-based, did not consider the socio-economic and environmental criteria of farming communities during the technology development process and evaluation (Tilahun Amede *et al*., 2006).

According to Tsedeke Abate (2006), the first extension program started by the former College of Agriculture based in a small village of Alemaya in 1953 with the main program comprised of research, extension and educational activities under one organizational umbrella. After a decade, the Ministry of Agriculture took the task of delivering extension service to improve the standard of living of farmers through the introduction of improved technologies (Belay Kassa and Degnet Abebaw, 2004). The present extension program, Participatory Demonstration and Training System (PADETS), was launched in 1995 with the main objective to attain adequate food production to meet food demand of the fast growing population of Ethiopia. PADETS pursues a package approach and demonstrates agricultural operations and results to the target community. These interventions include introduction of viable technology packages to: i) increase yield and improve livelihoods of the community through production of high value crops and increased diversification, ii) supply extension packages suitable to combat the effect of drought in the low moisture areas and deliver technologies to intensify livestock production, and iii) marketing services for increased food availability and income of pastoral households.

Agricultural research and extension based on this, Transfer-of-Technology (ToT) model, has a long history of innovations and increased effectiveness in food production. However, this ‗linear‘ model has limitations when issues are complex-such as the increasingly complex modern agricultural systems as well as the shift to sustainable development implying trade-offs between environmental, social and economic sustainability. According to Koutsouris (2008), the main problem with this linear model are: firstly, extension does not acknowledge farmers‘ experience and knowledge; secondly, general advice given on a regional scale often does not match individual farm conditions and the socioeconomic context of farmers, and; thirdly, advice is often seen to come out of a ‗black box‘, since the reasoning behind it is not transparent.

According to Berhanu G/Medhin *et al*. (2006), the major problems of the extension system in Ethiopia include top-down and non-participatory approach, primarily supply driven, low capacity of experts and development agents, low morale and high turnover of extension staff and shortage of operational budget and facilities. Also, extra responsibilities entrusted to development agents and weak linkages among extension, research and farmers have contributed a lot to the weakness of the extension delivery system. This shows that sustainable management of complex ecosystems need new approaches to learning, facilitation, institutional frameworks and policy support in contrast to ‗conventional–intensive‘ agriculture in which learning is seen as a social process where participants interact and negotiate to determine what socially is known (Koutsouris, 2008). Therefore, farming systems research and extension approaches are crucial to deal with complex adaptive systems of local farming systems that have co-evolved with human societies to fit local ecological conditions and satisfy human needs. Thus, for technology development, it is important to utilize farmers‘ knowledge, to search for the satisfaction of local people‘s objectives and to actively engage farmers in experimentation and technology design.

Agricultural extension and research systems of the country could not produce enough to feed an ever-increasing population, while expansion of agricultural land to ecologically fragile areas has threatened the natural resource base and future land productivity. Natural resources are depleted in the production process, reducing the production potential of the agroecosystems unless sufficient amounts of productivity raising investments are carried out.

2.6. Ensuring Sustainable Agricultural Production and Ecosystem Conservation

In Sub-Saharan Africa, the depth of poverty and hunger is already great and environmental degradation is further reducing the productive resource capacity. Thus, measures to be taken in the future for gains in food security requires clear, effective and synergetic strategies for sustainable agriculture and environmental conservation. Food and Agricultural Organization (FAO, 1991; Tesfaye Abebe, 2005) defines sustainable agriculture as the management and conservation of the resource base and the orientation of technological and institutional changes in such a manner as to ensure the attainment and continued satisfaction of human needs for present and future generations. Sustainable agriculture is a type of adaptation management encompassing a number of technologies, which together will produce high yields in a more sustainable manner than industrialized agriculture. Many technologies are based on and use ecological functions and services already existing in the agroecosystem. Sustainable development is environmentally none degrading, technically appropriate, economically viable and socially acceptable (Heitschmidt *et al.,* 2004).

Improving ecosystem and environmental productivity together with food security and rural livelihoods is one of the central views of sustainable development in rural areas (Buck *et al*., 2004). Therefore, sustainable land management as a knowledge-based procedure that helps integrate all ecosystem constituents including water, biodiversity and environmental management meet rising food and fiber demands while sustaining ecosystem services and livelihoods. Sustainable agricultural development strategy that is environmentally enhancing must be based on agroecological principles and on a more participatory approach for technology development and dissemination, and this may be the opportunity for solving the problems of poverty, food insecurity and environmental degradation (Altieri, 2002). The role of agroecology is to facilitate the design and management of sustainable food production systems and to investigate possible synergisms that can help alleviate food insecurity and natural resources degradation (Gliessman, 1998).

Experiences from Latin America, such as Cuba and Brazil as well as some Asian countries have shown that subsistence farmers can benefit from agroecological approach in sustainable agricultural production and protecting their environment. According to Altieri (1999), research and extension works conducted in Brazil using agroecological approach have brought significant on-farm impacts through crop yields increase, soil quality improvement and moisture retention and labor demand where maize yields have risen from 3 to 5 t per ha and soybeans from 2.8 to 4.7 t per ha. In addition, soils have become darker in color, moist and biologically active and fewer weeds, which imply labor saving for small farmers. The same report also noted that, most agroecological technologies promoted by NGOs have improved traditional yields per area of marginal land from 400-600 to 2000-2500 kg per ha enhancing also the general agrobiodiversity and its associated positive effects on food security and environmental integrity.

One of the biggest challenges of African development is to maintain food self-sufficiency in the face of increasing human populations, static or degenerating agricultural production and environmental degradation (Dovie *et al.*, 2003). Identifyication of agricultural technologies, which can contribute to the development of sustainable agricultural production is very important for food security, poverty alleviation and in conservation of agroecosystems of the country.

2.6.1. Agrobiodiversity conservation

Heywood (1996) defined agrobiodiversity as the variety and variability amongst living organisms (of animals, plants and micro-organisms strains derived from them) that are important to food and agriculture in the broad sense and associated with cultivated crops and rearing animals and the ecological complexes of which they form a part. It also includes a series of social, cultural, ethical and spatial variables that are determined by local farmers at the local community level (Jackson *et al.*, 2007). As human population increases, the demand for food increases and the pressure to generate more and more food in less and less space leads to a need for increased study of alternatives to conventional farming that could possibly meet this ever-increasing demand. One possible way of increasing food production while maintaining the existing cultivated area is by using agroforestry technologies which are some of the technologies of polyculture systems (Kruger *et al*., 1996). Agroforestry is the generic name used to describe an old and widely practiced land use system in which trees are combined spatially and/or temporally with agricultural crops and/or animals (Farrell and Altieri, 1995). Agroforestry optimizes the beneficial effects of interactions among woody species, crops and animals. It is also enhancing complementary relations among farm components, improved growing conditions, and efficient use of natural resources (space, soil, water, and light), and production is expected to be greater than in conventional land use systems.

Trees can enhance the productivity of a given agroecosystem by influencing soil characteristics, microclimate, and hydrology and associated biological components. Trees may affect the nutrient status of the soil by exploiting the deeper mineral reserves in the parent rock and by retrieving leached nutrients and depositing them on the surface as leaf litter. This organic matter increases the soil humus content, which in turn increases its cation exchange capacity and decreases nutrient losses. The added organic matter also moderates extreme soil reactions (pH) and the consequent matter availability of both essential nutrients and toxic elements. The association of trees with nitrogen – fixing bacteria and mycorrhizae will also increase available nutrient levels. Microorganism activity tends to increase under trees because of increased organic matter (improved food supply) and growing environment (soil temperature and moisture) (Farrell and Altieri, 1995). Trees produce a number of products important to both humans and animals. In addition to food and forage, they provide wood products, by-products such as oils and tannins and medicinal products. Tree crops can also supplement grain production.

As part of an ecological–based land management system, agroforestry practices can maintain ecosystem diversity and processes that contribute to long-term sustainability and environmental quality (Tesfaye Abebe, 2005). At farm, watershed and landscape scales, integration of agroforestry practices can transform agricultural lands into stable, resilient, diverse, aesthetic and sustainable agricultural land use systems. Agroforestry can sustain and improve crop yields as well as providing a range of additional resources, which includes erosion control and sediment, provide multiple crops including wood products, sequester and biodegrade excess nutrients and pesticides, moderate microclimates and diversify habitats for wildlife and humans. By utilizing trees for animal fodder and green manure, the integration of trees into crop and animal systems can add substantial nutritional inputs. Trees also maintain and improve structural and nutritional properties of soils through nitrogen fixation, soil aeration, and contributions to organic matter content and structural stability of the soil. Agroforestry is an effective and innovative means to reduce poverty, create food security and improve the environment.

Agrobiodiversity is a fundamental feature of farming systems around the world (Altieri, 1999). It encompasses many types of biological resources tied to agriculture, including genetic resources, edible plants and crops, livestock and freshwater fish, soil organisms vital to soil fertility, naturally occurring insects, bacteria, fungi and wild resources (Wood and Lenne, 1997). Biodiversity is necessary to sustain vital ecosystem structures and processes, such as soil protection and health, water cycle and quality and air quality. It also provides the genetic resources for the breeding of new, locally adapted crop varieties. Thus, habitat destruction is one of the biggest threats to biodiversity (Jackson *et al.*, 2007). Loss of agricultural biodiversity through the extinction of species, degradation of natural habitats and intensive modern agriculture based on a few breeds of animals and plants is occurring throughout the world at unprecedented rates (Ekesa *et al*., 2008). By combining agriculture and forestry production, various functions and objectives of forest and food crop production can be better achieved. There are environmental as well as socioeconomic advantages of such integrated systems over agriculture and/or forestry monocultures. Scattered trees on farm are common practice in Ethiopia and cover a large part of agricultural landscapes that have contribution in the improvement of livelihood of the rural people (Tesfaye Teklay, 2005), whereas little attention was given in research and development for optimum benefits from these resources.

Traditional agroforestry homegardens are common in the south and south-western parts of Ethiopia. This diversified agroforestry system is very important for proper functioning of the agroecosystems and livelihoods of the the households. Homegardens are mix of annual and perennial agricultural crops, tree and shrub species for household consumption or for income generation. According to Tesfaye Abebe (2005), homegardens are the most complex and diverse agroecosystems which fulfill ecological functions and economically more viable than other land use systems in the tropics because of the high-value cash crops comprised in them. The same author cited Fernandes and Nair (1986) and defined homegardens ‗as land use practice involving deliberate management of multipurpose trees and shrubs in intimate association with annual and perennial agricultural crops and invariably, livestock, within the compounds of individual houses, the whole crop-tree-animal unit being managed by the family labor'. Development and Promotion of proper management of homegardens could sustain the livelihoods of the poor households and bring about wealth to many households.

2.6.2. Use of improved agricultural technologies in the farming systems

Farmland in the developing world generally suffers from continuous depletion of nutrients as farmers harvest without fertilizing adequately or fallowing the land. Small-scale farmers have removed large quantities of nutrients from their soils without using sufficient amounts of manure or fertilizer to replenish fertility. This has resulted in high annual nutrient depletion rates of 22 kg nitrogen, 2.5 kg phosphorus and 15 kg potassium per hectare of cultivated land over the past 30 years in 37 African countries - an annual loss equivalent to $4 billion worth of fertilizers (Garrity, 2004).

Agriculture is an important economic activity in most countries and known to dominate the economies of developing countries in terms of its contribution to gross domestic products and supporting livelihoods (Chilonda and Otte, 2006). Agricultural intensification is one of the major drivers of ecosystem change and biodiversity loss as a consequence of associated land conversion, habitat fragmentation and agrochemical application, which needs effective management to avoid detrimental impacts on biodiversity and ecosystem services (Butler *et al*., 2009). Sustainable agricultural development is influenced by socio-economic and biophysical environments, resource endowment and production objectives (Amare Haileslassie *et al*., 2007; Sydorovych and Wossink, 2008). The structural composition and distribution of agroecosystem components vary among different types of agroecosystems at different scales. It also changes over time due to the influence of various factors both within and beyond an agroecosystem. Sustainable agriculture ranges from maintenance of a supportive biophysical resource base, the economic viability of production and the continuation of a sufficient supply of agricultural products to the social vitality of agriculture-based rural communities (Xu and Mage, 2001; Sydorovych and Wossink, 2008; Butler *et al*., 2009). For example, soil is one of the basic resource components that retains moisture and provides mineral substances so that the plant can perform various biological processes and grow (McCool *et al*., 2001). Organic content in the soil or thickness of top soil are crucial factors in determining the biophysical functioning of crop production. A diversified resource structure provides an opportunity to satisfy a variety of needs for different people. Also, the diversified agricultural landscape structure provides different amenity values that are appreciated by different people (Xu and Mage, 2001).

Agricultural technology can affect smallholder income, labor opportunities for the poor, food prices, environmental sustainability and linkages with the rest of the rural economy. Technological change in agriculture began at least 10,000 years ago, when the first cultivators selected wild plants and experimented with different growing environments. From those early beginnings, the technical performance of agriculture in the great civilizations remained roughly equivalent for centuries until the middle of the nineteenth century, where, principally in Europe and North America, the introduction of new machinery and sources of power, the rediscovery of Mendel's experiments leading to the development of scientific plant breeding and the development of artificial fertilizers, resulted in rapid increases in agricultural productivity (McCool *et al*., 2001).

Promotion of monocropping technologies by many scientists and extension workers as a better alternative to the farmers' traditional mixed cropping is perhaps one of the major factors responsible for the low adoption of these technologies and, consequently, the lack of desired impact on the production of farmers. Conventional farming systems have seriously degraded the soil resource base and reduced soil biological activity and diversity (McCool *et al*., 2001). On the other hand, in traditional mixed cropping systems, the diverse crop species usually are grown together and complement one another by using resources in different ways (Altieri, 1999). Scarce labor is efficiently utilized, weeds and insects are suppressed, erosion is controlled, there is sequential harvesting and the risk of total crop loss is averted. It has also been shown that diverse plant communities are more resistant to environmental stresses such as drought. It is now clear that technologies appropriate for monocropping cannot be transferred directly to mixed cropping systems without appropriate modification in order to have a sustainable production system.

Whilst new technologies are important for poverty reduction, if not carefully managed, they can create additional demand on resources, which may simply not be sustainable in the future. The most obvious example of this is water. For example, the lowering of water tables and loss of aquifer water, but also other resources, including biodiversity and chemicals, are also discussed here. Rainfed agriculture of the highlands has, as its major ecology, the mixed cropping system. There is, therefore, a need to develop and promote appropriate technologies that will improve productivity of this system. Traditional ways of farming, refined over many generations by intelligent land users, provide insight into sustainably managing soils, water, crops, animals and pests (Altieri, 1999). With crop mixtures, farmers can take advantage of the ability of cropping systems to reuse their own stored nutrients and the tendency of certain crops to enrich the soil with organic matter. Crops grown simultaneously enhance the abundance of predators and parasites, which in turn would prevent the build-up of pests. The plant diversity also provides alternative habitat and food sources such as pollen, nectar, and alternative hosts to predators and parasites.

Mixed crop-livestock production is the dominant production system in the Arsi Highlands of Ormia Region. Cereal crop production is the most important activity almost everywhere, while keeping cattle is usually the second most important. Other important occupations include raising other ruminant livestock (mainly sheep and goats), producing other storable annual crops (mainly pulses and oilseeds), vegetables and perennial crops (coffee, chat¸and fruit trees). The Arsi highlands have been the first areas of the country where modern technologies were introduced at the beginning of 1970s (Tsedeke Abate¸ 2006). These technologies have included use of improved cereal seeds, agrochemicals and intensive extension and research services. This conventional approach has brought about increase in agricultural production. These farming systems have been focused on certain cereal crops, particularly wheat and barley. As a result of mechanization and use of industrial chemical for fertilizing and protection of weeds and insects, most of the vegetation has been cleared.

Achieving agricultural sustainability in the country will be challenging to farmers, researchers and policy makers and will require fundamental changes in current farming systems. Based on the past experiences on national and international agricultural systems, taking traditional farming knowledge as a strategy point, a search has begun in the developing world for affordable, productive and ecologically sound small scale agricultural alternatives. Change in rainfall pattern and market fluctuation, government policies and top down extension system have exacerbated the peril of the farming communities.

2.6.3. *Agroecological approach in the agricultural production*

According to Francis *et al.* (2003), agroecology is the integrative study of the ecology of the entire food system, encompassing ecological, economic and social dimensions. This author citing Gliessman (1998) asserted that agroecology is defined as the application of ecological concepts and principles to the design and management of sustainable agroecosystems. It shows how natural systems can be used as templates or models for developing agricultural systems, which increase productivity and sustainability of agriculture while maintaining an environment that endures as well as provides quality of life. Therefore, agriculture will necessarily be composed of polycultures designed to benefit from spatial, seasonal and nutritional complementarity among species and draw largely on studies of plant interference and facilitation in natural communities. These diverse cropping systems encourage biological management of herbivores, weeds and diseases and, therefore, require knowledge of trophic interactions and models of pathogenesis. Sustainable agroecosystems will, then, reflect patterns of succession, energy flow and nutrient cycling similar to natural ecosystems.

Sustainable agriculture constitutes an important, progressive alternative to conventional agriculture, which reduces environmental degradation, preserves or restores the family farm and removes contamination from human consumption (Allen and Sachs, 1991). According to Gliessman (1998), the characteristics of sustainability include, at the very least:

- Having minimal negative effects on the environment and releasing no toxic or damaging substances into the atmosphere, surface water or ground water;

- Preserving and rebuilding soil fertility, preventing soil erosion, maintaining soils and ecological health;
- Using water in a way that allows aquifers to be recharged and the water needs of the environment and people to be met;
- Relying mainly on resources within the agroecosystem, including nearby communities, by replacing external inputs with nutrient cycling, better conservation and an expanded base of ecological knowledge;
- Working to value and conserve biological diversity, both in the wild and in domesticated landscapes, and
- Guaranteeing equality of access to appropriate agricultural practices, knowledge and technologies and enabling local control of agricultural resources.

According to Altieri (1999), agroecological approach offers an alternative path to agricultural intensification by relying on local farming knowledge and technologies adjusted to different local conditions, management of diverse on-farm resources and inputs and incorporation of contemporary scientific understanding of biological principles and resources in farming system. It also has the potential to reverse the anti-peasant biases inherent in strategies that emphasizes on purchased inputs and machinery, valuing instead the assets that small farmers already possess, including local knowledge and the low opportunity costs for labor.

The concept of ‗sustainable agriculture' is today gaining ground, which is introduced to cover and pay tribute to all these different aspects of the use of land (van Keulen, 2007). Sustainable agriculture is based on recognizing and building on locally-available resources and natural processes, including encouraging nutrient recycling and biodiversity conservation and limiting the use of external inputs of agrochemicals and non-renewable energy. A basic principle is full participation of farmers and rural people in all processes of problem analysis and technology development, adoptions and extension (Hamilton *et al.*, 2003). These include the interaction between crop plants and insects, soil microorganisms, weeds and many other elements of the local environment. The ultimate goal of these efforts is to design agroecosystems that blend ecological concepts of integrated pest control and organic fertilization with elements of traditional polyculture - the cultivation of several species of crop plants in a single plot, often intermixed with semi-cultivated plants (Martin, 1995).

Agroecological initiatives in different countries have shown that traditional crop and animal systems can be adapted to increase productivity by biologically re-structuring peasant farms, which, in turn lead to optimization of key agroecosystem processes (nutrient cycling, organic matter accumulation, and biological pest regulation) and efficient use of labor and local resources (Altieri, 1999). Although traditional farming and pastoral systems encompass a remarkable diversity of crops, livestock and grasses in Ethiopia, the diversity has been eroded and lost over time, which jeopardizes food security and increases risks for local people (Melaku Worede, 1992).

Achieving agricultural sustainability in Ethiopia will be challenging to producers, researchers and policy makers and will require fundamental changes in current farming systems. Sustaining the natural resource base will help agricultural productivity growth, and this will lead to poverty alleviation. In the short run, there might be trade-offs among the objectives of economic growth, poverty alleviation and sustainable agricultural production taking into account the short-term perspective of the individual farmer to satisfy the basic needs of the household. Self- sufficiency and survival demanded a symbiotic relationship between human communities and their natural environment.

Farmers need to have the incentive and the capacity for a sustainable intensification of agriculture. Several factors such as policies, technologies, institutions, and population pressure and agroclimatic conditions can affect the links between sustainability, growth and poverty alleviation by influencing the choices of households and communities. The farming system approach considers both biophysical dimensions (such as soil nutrients and water balances) and socio-economic aspects (such as gender, food security and profitability) at the level of the farm-where most agricultural production and consumption decisions are taken. The power of the approach lies in its ability to integrate multi-disciplinary analyses of production and its relationship to the key biophysical and socio-economic determinants of a farming system.

The resource endowment of any particular farm depends on population density, the distribution of resources among households and the effectiveness of institutions in determining access to resources. Regardless of their size, individual farm systems are organized to produce food and to meet other household goals through the management of available resources - whether owned, rented or jointly managed – within the existing social, economic and institutional environment. The functioning of any individual farm system is strongly influenced by the external rural environment, including policies and institutions, markets and information linkages.

Therefore, the conventional methods have not equally affected the whole farming communities. Based on local criteria, there are three wealth groups: rich, medium and poor. The purpose of this study was to identify the best practices of agricultural technologies, which incorporate elements of both traditional knowledge and modern agricultural science, featuring resource-conserving yet highly productive systems. It also provides an overview of major factors affecting agricultural sustainability in the Arsi highlands and identify challenges that must be overcome to achieve long-term sustainability of agricultural production through ecosystem conservation.

3. OBJECTIVES

3.1. Main Objective

The main objective of the study was to assess existing farming systems including traditional and modern or combined farming systems and identify the best practices for sustainable agricultural production and agroecosystem conservation.

3.2. Specific Objectives

The specific objectives of this study were:

(1) To assess the socio-economic situation of the farming communities and their farming practices;

(2) To record agricultural crop diversity at different traditional climatic zones and compare agricultural practices carried out by different wealth groups;

(3) To compare annual agricultural crops, income, and cost and benefit of the HHs;

(4) To record tree and shrub diversity at forests, farms, pasturelands and in homegardens and their distribution along the weredas and traditional agricultural zones;

(5) To identify the main factors involved in the agricultural production; and

(6) To identify the best farming system practiced by the farmers, this can contribute to the sustainability of agricultural production and conservation of natural resources.

4. MATERIALS AND METHODS

4.1. Description of the Study Area

The study was conducted in Arsi Zone, Oromia National Regional State (6^0 45‘ to $8^0$58‘ N and 38^0 32‘ to 40^0 50‘ E covering a total area of 23,821 km^2). The study covers four weredas, namely, Dodota, Lode-Hetossa, Tiyo and Digelu-Tijo, located 125-200 km southeast of Addis Ababa. Arsi Zone shares borderlines with the West Arsi Zone, East Shewa, Bale and Western Hararge Zones. Asella, the capital town of the Zone, is found 175 km southeast of Finfinne (Addis Ababa) on Finfinne-Adam-Robe road (Fig. 1).

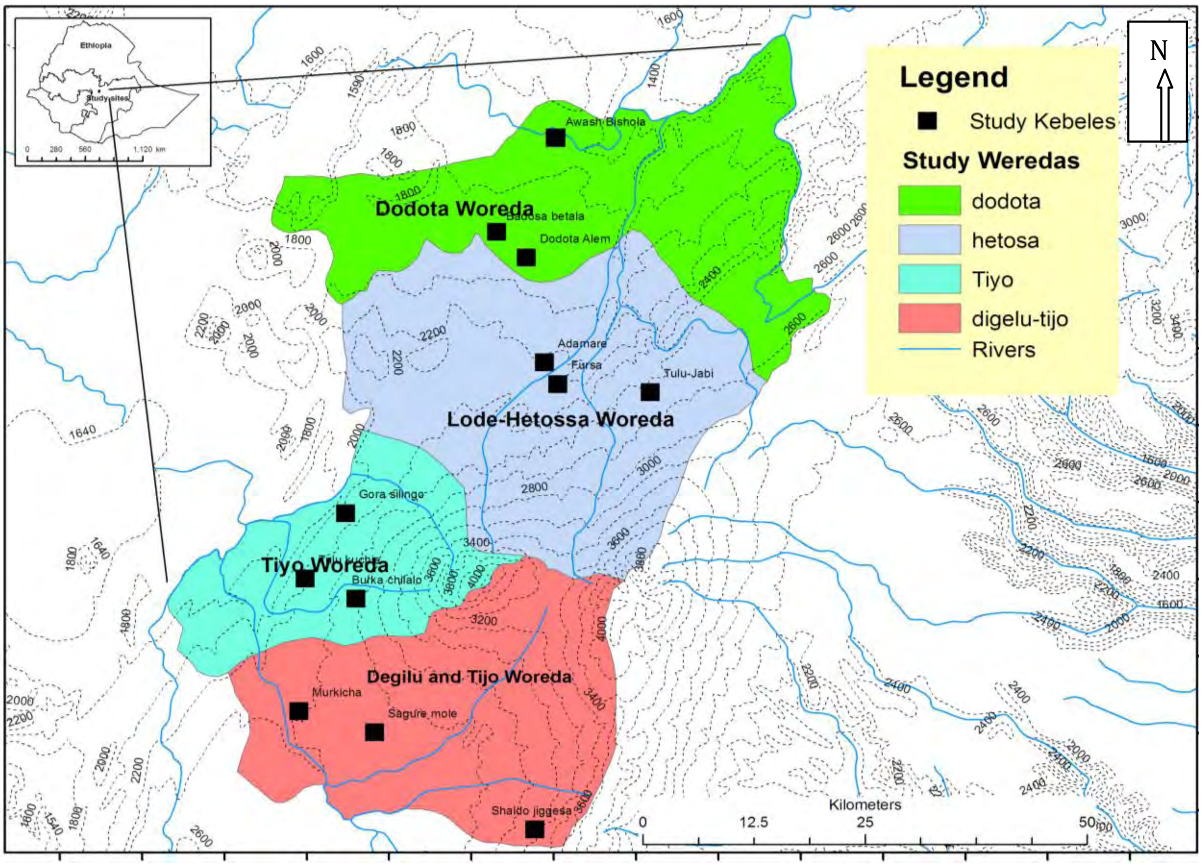

Fig. 1. Map of the study sites

4.2. Physical and Biological Settings of the Study Sites

4.2.1. Topography and climate

The study weredas are characterized by high and rugged mountain ranges, which are flat-topped, deep gorges of rivers and rolling plains. The altitudinal range of the Zone is from 500 to 4,245 m a. s. l. with the highest mountain peak of Mt. Kaka. The climatic condition of the Zone varies from lowland to cool highland and from arid to high rainfall areas. The annual average temperature ranges from 10 to 30^{0}C and mean annual rainfall ranges from 700-1400 mm. The study was conducted in 12 kebeles of the four weredas in Arsi Zone of Oromia Region. These kebeles cover three traditional agricultural zones, KOLLA, WEYINA-DEGA and DEGA. The altitude of the 12 kebele ranges from 1441 to 2968 m above sea level (Table 1). The mean annual rainfall varies from 500 to 1400 mm and temperature ranges from 10^{0}C to 30^{0}C. The climate diagram of the nearest meteorological stations to the study sites (Melkasa, about 5 -10 km from Dodota wereda kebles; Kulumsa, about 42 km from Lode-Hetossa and 2-7 km from Tiyo Kebeles; and Bekoji, about 25 km from Digelu-Tijo Kebeles) presented below (Fig. 2 and 3).

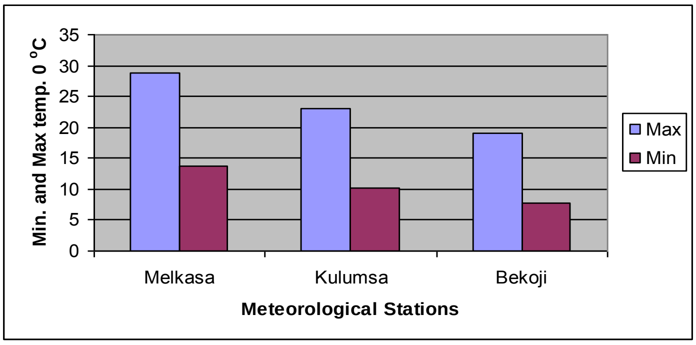

Fig. 2. Average min.and max. temperature of the study sites (1966 – 2006): Source: Unpublished NMSA (2009):

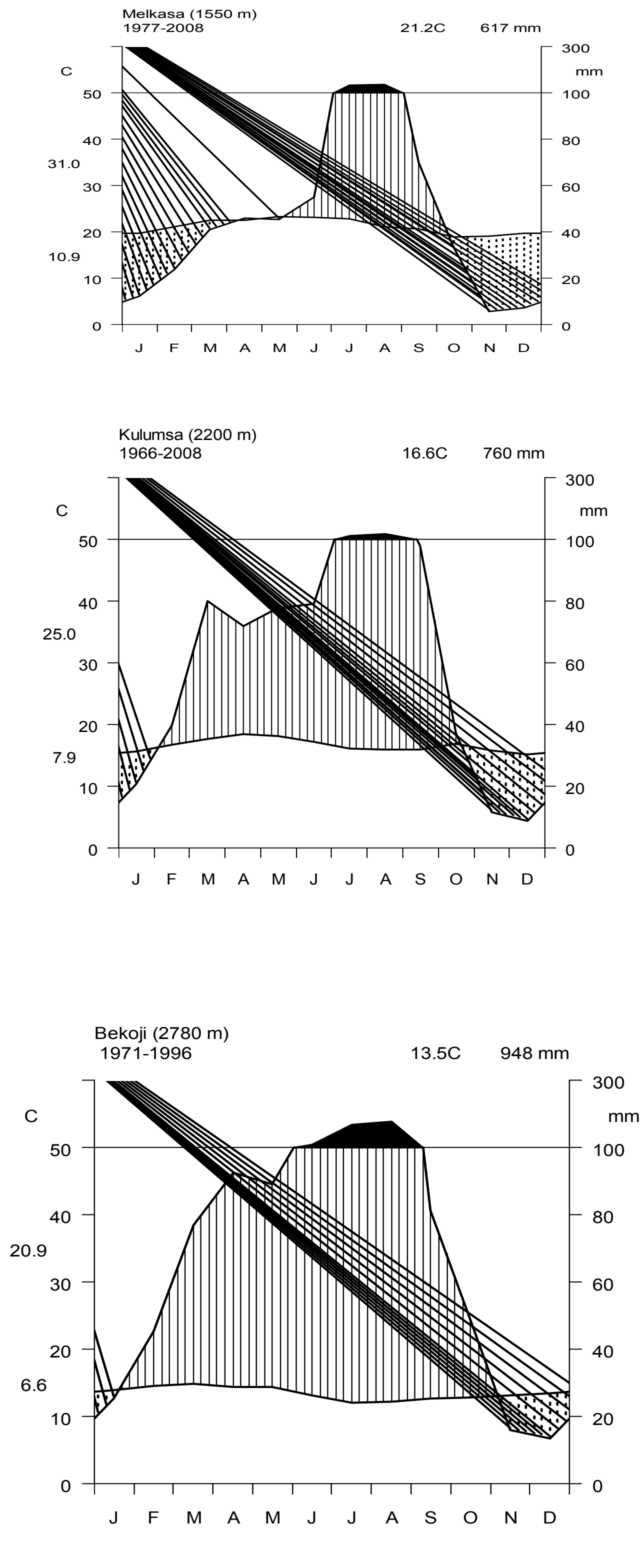

Fig. 3. Climate diagram of Awash Melkasa, Kulumsa and Bekoji, the nearest meteoroogical stations to the study sites (Source of raw data: umpublished Ethiopian National Meteorological Services Agency).

The altitudinal differences of the study sites ranges from 1441 to 2968 m.a.s.l., which has contributed to the variation of rainfall and temperature from the lowlands of Dodota Wereda to the Digelu-Tijo Wereda highlands (Table 1).

Table 1. Physical characteristics of the study sites

No.	Wereda	Kebele	Location			Mean Annual Rainfall (mm)	Mean annual Temp. (^{0}C)
			Latitude (N)	Longitude (E)	Altitude (m)		
1	Dodota	Awash Bishola	$8^0$24'	39^0 20'	1441		
		Badosa Betela	$8^0$16'	39^0 16'	1715	500-900	18-30
		Dodota Alem	$8^0$15'	39^0 18'	1759		
2	Lode-	Adamare	8^0 9'	39^0 19'	2032		
	Hetossa	Fursa	8^0 8'	39^0 20'	2035	500-900	10-27
		Tulu-Jabi	8^0 7'	39^0 26'	2459		
3	Tiyo	Gora Silingo	7^0 59'	39^0 7'	2121		
		Tulu Kuchie	7^0 55'	39^0 5'	2238	500-1050	23-27
		Burka Chilalo	7^0 54'	39^0 8'	2572		
4	Digelu-Tijo	Sagure Mole	7^0 45'	39^0 9'	2467		
		K/Murkicha	7^0 46'	39^0 4'	2389	900-1400	15-22
		Shaldo-Jigessa	7^0 39'	39^0 19'	2968		

Source: Ethiopian Meteorological Agency and field measurements

4.2.2. Geology and soils

According to the Atlas of Arsi Zone (2004), most of the volcanic rocks in Arsi are formed during Cenozoic era. In the Tertiary period of Cenozoic era, there was wide spread volcanism induced by extensive fracturing and subsequent faulting. During this period, the outpouring of lava along fissures covered the present highland parts of Arsi Zone. This has created thick lava basalt rocks of the trap series. The trap series cover almost the central plateaus and massif of Arsi.

About 25 types of soils are found in the Zone, where some are found only in small localities. The dominant soils are: i) *Chromic and Pellic Vertisols*: the most frequently seen soil types covering 30% of the zone, ii) *Dystric, Chromic, Eutric, Calcic and Vetic Cambisols:* the second dominant soil type constituting about 23% of the zone, iii) *Luvisols*: a third dominant type constituting 13% of the Zone's total area, iv) *Dystric, Eutric Nitosols*: covering about 9% of the total area of the Zone, v) *Lithosols*: this group of soils is the most dispersed soil group found in Arsi; vi) *Mollic and Vitric Andosols*: this type could form other soil group having over 60% vitric, volcanic ash, or other vitric pyroclastic materials in silt, sand and gravel fraction, and vii) *Fluvisols:* this soil group contains calcaric, calcic and eutric fluvisols, which together constitute about 2% of the total soil groups found in the Zone.

4.2.3. Land tenure and land-use type

In Ethiopia, land belongs to the Government and the public. Landholders have only use rights. Land-use system in the Arsi Zone can be categorized into: forest, agricultural land, pastureland and settlement area. Cultivated land represents about 53% of the total area (Atlas of the Arsi Zone, 2004). This includes (mono-and biannual cropland), plantations (enset, sugarcane), horticulture and pastoral farming. The major cultivated lands are found in Digelu-Tijo, Limu-Bilbilo, Robe, Hetossa, Amigna, Merti, Dodota, Sire, in some parts of Sude, Tiyo, Seru, and Munessa weredas. Major farming systems practiced in the Zone are mixed farming, mechanized and traditional. Arsi is one of the intensively cultivated zones in the region due to favorable conditions, which are the result of good rainfall, moderate temperature, fertile volcanic soil and undulating to rolling plateau.

4.2.4. Vegetation

According to natural vegetation classification of Ethiopia and Eritrea by Sebsebe Demissew and Friis (2009), the study area covers two vegetation types: dry evergreen montane forest and grassland complex and Afro-alpine and sub-Afroalpine (Table 2). According to the Atlas of Arsi Zone (2004), the Afro-alpine high vegetation accounts for about 4% of the total area. The low temperature of the area is an inhibiting factor for tree growth except some low bushes, tuft grasses and lichens. Some of the plants are succulent, and some are cushion forming in order to minimize exposed surfaces, and even spiny. They are also slow growing and of low stature, with the aerial parts or only just above the ground level, however, grow to 3 m in height. On slopes where water does accumulate, the vegetation consists of meadow grasses and herbs. Mole rats and other species of rodents abound in the meadow and the ground is often spongy owing to their underground tunnels.

On the flatter ground where water accumulates, aquatic species are common. Various herbs grow on rocky outcrops where soil is found in crevices. Mosses and lichens also occur here. Lower down in altitude, in the sub-Afroalpine zone, the most extensive vegetation is *Erica* scrub. Originally, this scrub may have been woodland, if left unburnt. The *Erica* scrub occurring on slopes, grows on very thin soil, there often being practically no soil under the decaying plant remains.

Conditions of plant growth, especially soil temperature, are more favourable than higher up in the Afroalpine zone. The areas of thicker soil in the Sub-Afroalpine supports more species of woody plants with the deepest well-drained soils at the lower altitudinal limits supporting *Hagenia abyssinica* trees as well as many species of herbs.

Dry evergreen montane vegetation covers about 5% of the total area. This region is dominated by 30 to 40 m high *Juniperus procera* and *Podocarpus falcatus* and broad-leafed trees in its second layer. The juniper forest region is dominated by *Hagenia abyssinica* at its very humid part. The ground is covered with grasses and various other herbs including ferns and mosses. The upper altitudinal limits also consist of simpler forests of *Hagenia abyssinica* with associated small trees or shrubs of *Hypericum revolutum* and *Myrsine melanophloeos* on deeper soils and *Erica* scrub on thinner soils of the slopes.

Woodlands account for about 13% of the total area of the Arsi Zone. They are found interspersed with moderately cultivated lands. Shrub lands account for about 15% of the total area. Grasslands accounts for about two percent of the total surface. It is the best rangeland for grazing. Swampy, marshy, lake and ponds areas account for about two percent of the total area. Riverine vegetation accounts for about five percent of the total area and is found along flood plains and the banks like Wabishebele, Keleta and Shenen Rivers.

Table 2 Vegetation types and associated plant species of the study area

Vegetation type	Altitude (m)	Rainfall (mm)	Associated plant species
Sub-Afroalpine and Afro-alpine	> 3100	800-1600	*Kniphofia* spp., *Aeonium leucoblepharum*, *Helichrysum citrispinum*, *Alchemilla* spp. *Lobelia rhynchopetallum*, *Agrostis quinqueseta*, *Festuca schimperiana*, *Trifolium acaule*, *Luzula abyssinica*, *Thymus* sp., *Arabis alpine*, *Epilobium hirsutum*, *Hebenestretia angolensis*, *Ranunculus* spp., *Veronica* spp., *Oreophyton falcatum*, *Erica arborea*, *E. timera*, *Hypericum revolutum*, *Gnidia glauca*, *Myrsine melanophloeos* and *Hagenia abyssinica*
Dry evergreen montane vegetation, woodland and grassland complex	400-3100	250-1300	*Juniperous procera*, *Podocarpus falcatus*, *Hagenia abyssinica*, *Olea europaea* subsp. *cuspidata*, *Acacia abyssinica* or *Acacia negrii*, *Prunus africana*, *Apodytes dimidiata*, *Allophyllus abyssinicus*, *Euphorbia ampliphylla*, *Myrsine melanophloeos*, *Olinia rochetiana*, *Discopodium penninervium*, *Myrsine africana*, *Calpurnia aurea*, *Dovyalis abyssininca*, *Smilax aspera*, *Rubia cordifolia*, *Urera hypselodendron*, *Embelia schimperi*, *Jasminum* spp., *Hypericum revolutum*, *Myrsine melanophloeos*, *Cenchrus ciliaris*, and *Chrysopogon aucheria*

Source: Atlas of Arsi Zone (2004)

4.2.5. The people of the study area

Based on the 1994 ―population and housing census report" of the Central Statistics Authority on Oromia Region, the estimated population of the Zone is 2,272,915 (49.8% males and 50.2% females). The average household sizes for Arsi zone is 5.2 of which 5.3 persons per household reside in rural areas while 4.6 persons per household for urban areas.

4.3. Methods

4.3.1. Selection of the study sites

The Arsi Zone is divided into 24 weredas. In order to have a fair representation of the agricultural systems across the Zone, stratified sampling procedure was followed to collect data at three levels; wereda, kebeles and households. Based on traditional zonation, four weredas (Digelu-Tijo, Lode-Hetossa, Tiyo and Dodota) were chosen for sample weredas to represent possible local variations (i.e. one from weredas covering only DEGA, two weredas stretching over DEGA, WEYINA-DEGA and KOLLA and one wereda which covers only KOLLA). These weredas cover 18% of the land area and constitute 26% of the population of the Zone. Also, the selected weredas are representing all the land-use types in the Zone. In each wereda, 3 kebeles were selected on the basis of crop production, traditional climatic zones (KOLLA, WEYINA-DEGA, and DEGA kebeles), agricultural diversification potentials and access to market outlets.

4.3.2 Sampling methods of the households

The lists of Kebele in each wereda were obtained from Agriculture and Rural Development Office. Then, these kebeles were grouped into three traditional climatic zones (Kolla, Weyina and Dega). One kebele from each climatic zone was randomly selected. All the kebele members of these selected kebeles listed and grouped into through wealth groups by the experts from Agricuture and Rural Development Office and kebele Administrators based on local criteria. Stratified random sampling technique was applied to identify sample households with the combination of rich, medium and poor farmers and land use systems of each selected households (i.e., farmlands, pasturelands and homegardens) following the approach described by Gomez and Gomez (1984) applied by (Tschakert, 2007). Within each kebele, 15 households were selected on the basis of their wealth group. All households were categorised into poor, medium and rich by the communities based on local criteria. Accordingly, five households were randomly selected from each category of economic group of farmers, making a total of 15 households per kebele and 180 households for the study area.

4.3.2. Methods of data collection and analyses

4.3.2.1. Data collection

Qualitative data and information can have strong explanatory power and they are often needed for obtaining deep understanding of a situation. Quantitative data are also important for obtaining an overview of the situations in time and space, and thus much used in planning. By combining the two, the generality of the qualitative data could be assessed and process explanations of quantitative data be obtained (Sandewall, 2001).

Data were collected at three levels: wereda, kebele and households. At the first two levels, general information were collected on the biophysical and socioeconomic conditions using semi-structured interviews and pre-prepared checklists (Annex 7). At Wereda level, information was collected in three ways: i) from secondary sources, ii) through observation made during reconnaissance surveys of weredas, and iii) through interviews with professionals in the respective agricultural offices. At the kebele level, data were collected through the use of key informants and discussions with kebele administrators and development agents. The information collected at wereda and kebele levels were used to understand the overall setting of the research sites.

At the household level, data were collected from all farm fields (cultivated land, pastureland and homegarden) of each household using measurements, interviews and observations. Prior to interviews, the farms were visited to make observations on the overall conditions of the farming systems of the area. Heads of the households with their wives (when applicable) were involved in the interviews. Data were collected on biophysical and socio-economic characteristics of the farms using PRA tools, structured and semi-structured interviews of the households and key informants, Focus Group Discussions (FGDs) and physical observations. Households' information included: i) family size, labor force, age, and educational status; ii) products (crop, livestock and forest); iii) production outputs and inputs; and iv) the unit cost associated with each product (Dovie *et al*., 2003). These data were collected by the investigator and enumerators during the years 2007 and 2009. The enumerators were agricultural technicians who were employed from the respective localities for the purpose of data collection. These technicians had diploma level training in agriculture and natural resources management and speak Afan Oromo, the local language. They were trained by the investigator on the methods and approaches of data collection.

4.3.2 Data analyses

Discriptive statistics was used for the analyes of socioeconomic characteristics of the households. Computer software SPSS (13.0) for window and Excel (2002) were used to summarize and analyse the number of family members, age distribution, educational background, landholdings and animal population. ANOVA was performed using data from socioeconomic and biophysical studies of the households grouped into rich, medium and poor wealth groups living in the three traditional climatic zones as replicants of the test.

4.3.3. Diversity and distribution of crop, tree and shrub species

4.3.3.1. Methods of data collection

Data on perennial and annual crop types, land area, production quantity and cost of production were collected. Information on the local prices of agricultural crops was gathered. Also, all tree and shrub species in the farmland, pastureland and homegardens were listed by sample households, key informants and during focus group discussions. For each household, the land area and different species of crops, trees and shrubs were identified and enumerated. Ethnobotanical study was conducted using semi-structured interviews. One hundred eighty households were interviewed and their knowledge on the ecology and use of plant species were recorded. As part of the interviews, a guided-tour technique was employed which consisted of walking through the forest, farmland, pastureland and in homegarden with one or more informants in order to observe the plants cited and to collect samples for posterior botanical identification.

In order to capture as much local knowledge as possible, many knowledgeable farmers have been involved in the study. It is assumed that the elderly and most well recognized members of community are more likely to possess the majority of the knowledge held within the community (Pfeiffer and Bultz, 2005). The uses of each tree and shrub species were identified by the household heads, key informants and during FGDs. The data were, then, compiled and screened/refined for analysis. This exercise gave the participants the possibility of listing rare species which were very important in the past but highly threatened due to over-use. In addition to 180 sampled households, 5-7 key informants and 15-20 focus group discussants participated in the survey. The key informants and FGDs participants were interviewed on changes in vegetation cover of their areas over times.

Some of the common species were identified at field level while voucher specimens of all tree and shrub species were collected from forests, farmlands, homegardens and pasturelands and information was gathered on scientific name, common name and ethnobotanical use. Specimens were then identified to species levels at the National Herbarium (ETH) of Addis Ababa University. Ethnobotanical data were classified into 11 major plant use categories. All plants collected were either assigned to one or more of these categories. Specimens were dried and deposited in the National Herbarium (ETH) of Addis Ababa University.

4.3.3.2. Data analysis

Diversity, evenness and distribution of agricultural crops, tree and shrub species: Species diversity is the total number of crop species on farm, tree and shrub in forests, farms, pasturelands and homegardens. Shannon and Wiener Index (Shannon and Wiener, 1949) and Evenness measure (E) (Pielou, 1969; Margurran, 1988; and Huston, 1995), which are commonly used tools for these purposes were computed to indicate the relative proportion or abundance of a particular species in the forests, farms, pastureland and homegardens.

The Shannon-Wiener diversity Index (H') is high when the relative abundance of the different species in the sample is even and is low when few species are more abundant than the others. It is based on the theory that when there is a large number of species with even proportions, the uncertainty that a randomly selected individual belongs to a certain species increases and, thus, the diversity. It is calculated using the formula $H' = - \sum p_i \ln p_i$ (Magurran, 1988), where p_i is the proportion of crop area composed of species *i*. An additional measure of diversity, which compares the observed distribution with the maximum possible even distribution of the number of species in the sample (Pielou, 1969) was calculated. The measure of Evenness (*E*) is the ratio of observed diversity to maximum diversity and it was calculated as $E = H'/Hmax = H'/lnS$ (Magurran, 1988), *S* is species diversity index. *E* has values between 0 and 1.0, where 1.0 represents a situation in which all species are equally abundant.

Variations in composition of species among the different kebeles were determined using Jaccard's similarity Index (Magurran, 1988. It is calculated Cj = *j/ (a+b-j); where j* = the number of species shared by any two sites a and b,

a = the number of species in site a, and; *b* = the number of species in site b

Simpson'index was calculated for the diversity of tree and shrub species. If there are S species and *n* is the number of individuals of the species and N is the total number of individuals, then Simpson's index (which = 1 - D) is calculated using the formula:

$$D = \sum n (n-1)/N (N-1)$$

Simpson's Index (D) measures the probability that two individuals randomly selected from a sample will belong to the same species (or some category other than species). The value of this index also ranges between 0 and 1, and the greater the value, the greater the sample diversity.

Classification of tree and shrub species: Cluster analysis using Euclidean distances of hierarchial grouping was performed to identify vegetation community types (Digby and Kempton, 1987). In ecology, cluster analysis is used to classify sites, species or variables into groups based on their similaries.

Production and economic values of agricultural crops: The quantities and direct-use values of the output of crops produced were calculated on household basis for user households and across all sampled households. The monetary values of products were calculated from known and existing prices quoted in the village and nearby markets. Data were analysed using descriptive statistics and presented as means and standard errors. The value of an individual product was calculated using the formula: VP= $p_i q_{i;}$ where, VP = value of products; p_i, = unit price of the ith resource; q_i = quantity of the ith resource produced by the jth household. When the total quantity of resources is given as k, and n, p_i, q_i defined as above, the values of all the resources produced by all households is given by: $\sum p_i q_{i1} + \sum p_i q_{i2} + \sum p_i q_{i3}$ …….. $\sum p_i q_{in;}$ If n = the number of individual households then the value of the ith resources produced by j = 1, 2, 3 …… $p_i q_i n$.

Monetary values were calculated for benefits derived at various stages of production, consumption and sales, taking into account the cost of production (labor, fertilizer, seed, ploughing, threshing, implements, land lease).

Cost and Benefit Analysis for agricultural crop productions: The cost and benefit analysis measures the profitability of the new technology and its components represented by the test factors.

B = $\frac{R}{C}$; where B is benefit ratio, R sum of returns and C is sum of costs corresponding to traditional and adopted new technology.

Ethnobotanical data analysis: The relative importance of tree and shrub species to local people was estimated using the methods of quantitative ethnobotany. The local importance of each species was calculated using two different techniques: Use-value (UV) and Relative Importance (RI). The Use-value was calculated using the formula UV = ΣU_i /n (Rossato *et al.* 1999; Silva *et al.*, 2006), where, U_i = the number of uses mentioned by each informant for a given species, n = the total number of informants.

Relative Importance (RI) was calculated using the formula RI = NUC + NT (adopted from Bennett & Prance 2000), where: NUC = number of use categories of a given species (NUCS) divided by the total number of use categories of the most versatile species (NUCVs); NT = is given by the number of types of uses attributed to a given species (NTs) divided by the total number of types of uses attributed to the most important taxon (NT-MIT), independent of the number of informants that cite the species.

Use of different computer softwares: SPSS 13.0 for Windows (2004), Excel (2002) and PAST (Hammer *et al*., 2007) were used to analyze the generated data. ANOVA was used to test the significant differences: i) among the rich, the medium, and the wealth groups; ii) effects of different agricultural technologies on income of the wealth groups was tested; and iii) variations of different weredas of the study area in resources endowment. Outcomes were then summarized to identify factors influencing agricultural production and ecosystem conservation.

5. RESULTS

5.1. Socioeconomic Characteristics

5.1.1. Social characteristics

The respondent households constituted 87% male and 13% female household heads. The number of family size varied among the households which ranged from 2 to 18. About 77% of the respondents had five or more family members in the household. The mean family size ranged from 5.7 to 7.3. The mean family size of the rich and medium wealth groups was the same but higher standard deviation for the medium wealth group ($\pm$1.9) than the rich households ($\pm$1.1). The overall mean family size for the respondents was 7.0 $\pm$1.

About 76% of the respondents were Oromos, 23% Amharas and one percent Gurages. Regarding the respondents' religion, 62% of them were Christians (60% Orthodox and 2% Protestant) and 38% were Muslims.

Different age groups were included in the sampled households. Fig. 4 shows the age distribution of respondents in the study area rangesd between 18 and 70 years (Fig.4.). The modal age group falls in the 36-45 years age group.

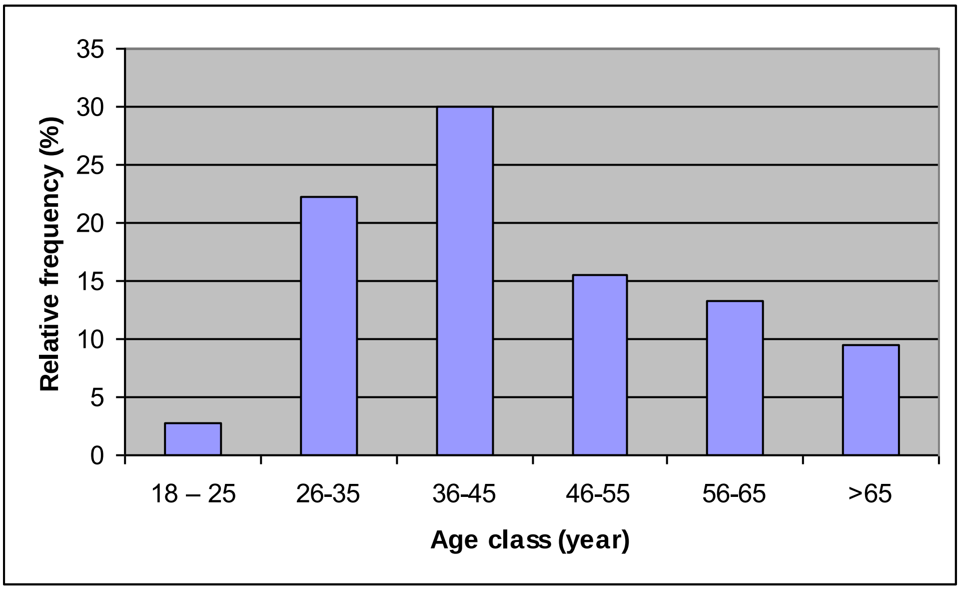

Fig. 4. Age distribution of the respondents

The study revealed that the mean age distribution of the wealth groups poor, medium and rich was 41.7, 45.9 and 49.6 years, respectively. The age group distribution for the three wealth groups showed that 51, 36 and 28% of the rich, medium and poor, respectively, were found to be above 45 years of age. The study showed that the mean age of the rich > medium> poor wealth group (Fig. 5). The age difference was significant at $P < 0.05$. This implies that the wealth status of the households was related to the age of the household head. The older heads of the households had rich experiences in the use of agricultural technologies.

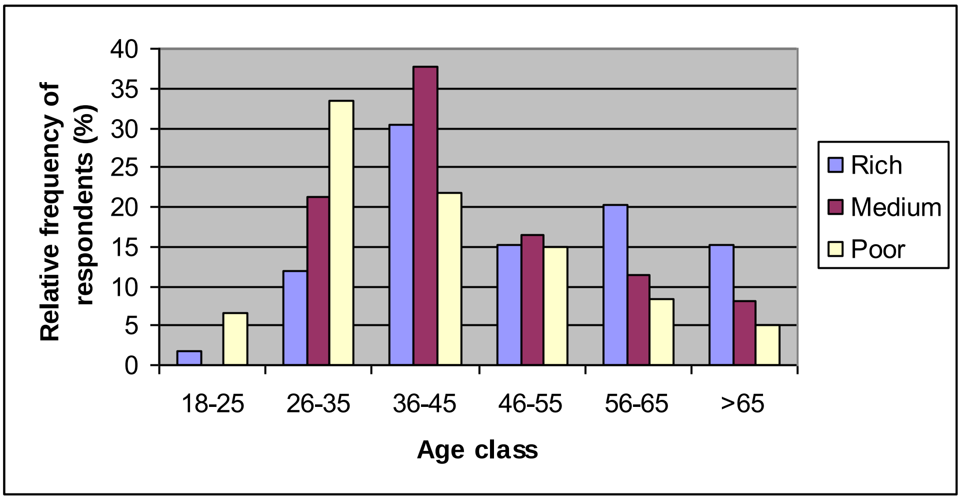

Fig. 5. Age distribution according to wealth status

The sampled households had different educational background, which ranged from illiterate to secondary school education. The majority of farmers in the study area have primary education. Thirty six percent (20% illiterate and 16% read and write) of the respondents had no formal education, while 41 and 19% had primary and secondary education, respectively (Fig. 6).

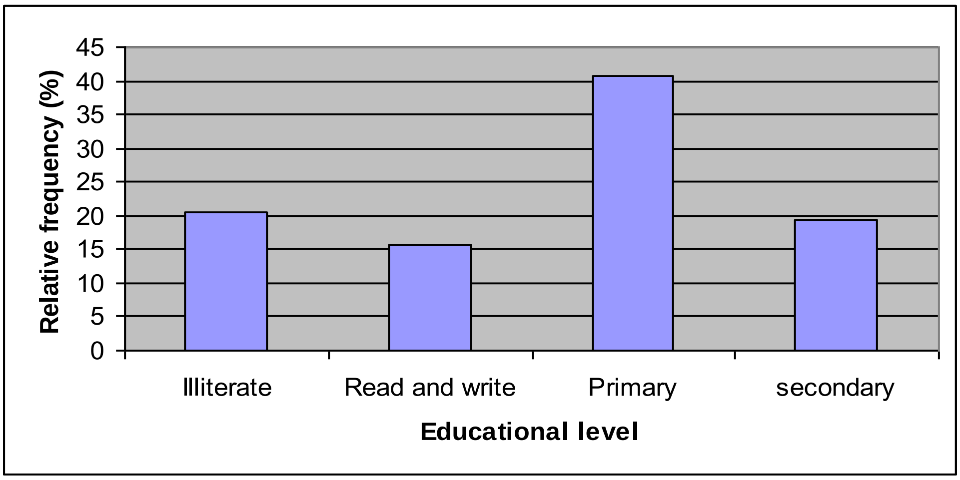

Fig. 6. Educational status of the respondents

The study showed that 34, 48 and 40% of the rich, medium and poor wealth groups, respectively, attended primary school, while 25, 21 and 12% of the rich, medium and poor, respectively, attended grades 9-12 (Fig. 7). There were significant differences among the wealth groups in educational level at P < 0.05.

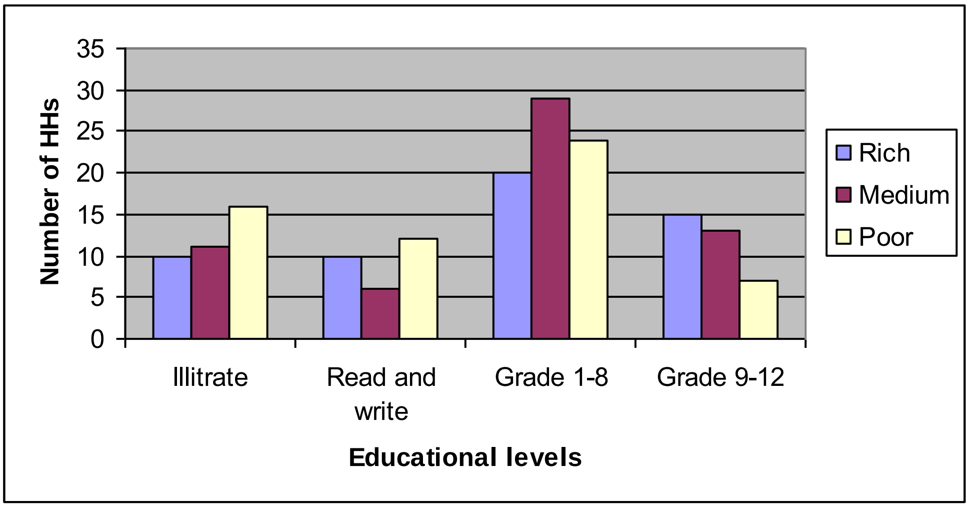

Fig. 7. Educational level of the respondents of the three wealth groups

5.1.2. Socioeconomic situation

Landholdings of the households varied highly from less than 0.5 ha to more than 8 ha. The mean landholding of each household was about 2.7 $\pm$ 1.6 ha. About 42% of the households had less than or equal to 2 ha and 53% had less than or equal to 2.5 ha. Only 16% of the households have more than 4 ha of landholding (Fig. 8).

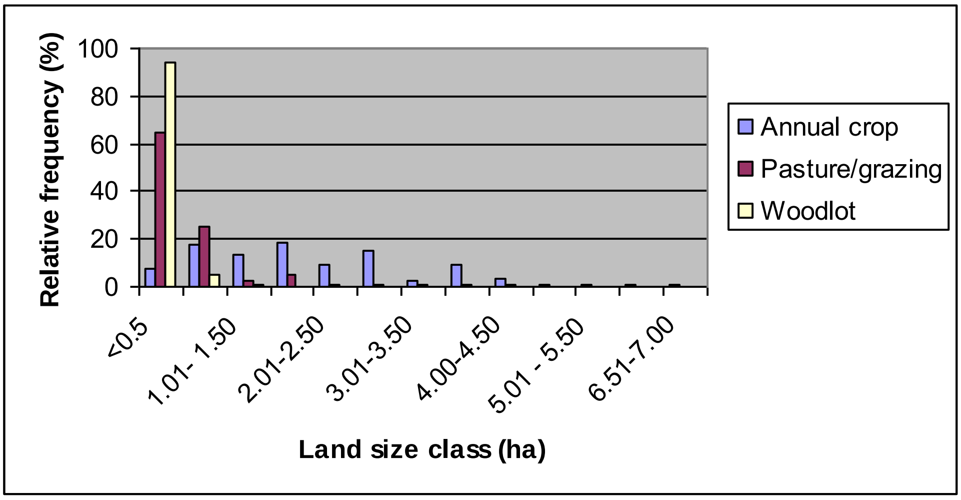

Fig. 8. Farm size distribution of the respondents

The rich farm households owned more land than the medium, and the medium households owned more land than the poor households. It was also found that the rich households had more agricultural land (3.5 ha) than medium (2.8 ha) and medium households had more than the poor households (1.8). About 42% of the poor households had less that 1 ha. On the other hand, 83, 59 and 33% of the rich, medium and poor, respectively, had landholding more than 2.0 ha (Fig. 9). There was significant difference ($P < 0.05$) in landholding sizes among the wealth groups.

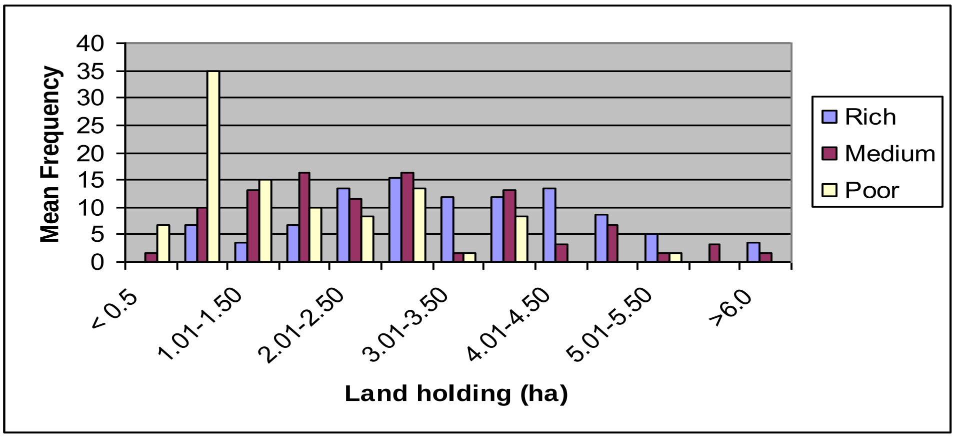

Fig. 9. Landholding size of the wealth groups

Average landholding was the highest at Dodota (3.1 ha) and the lowest at Lode-Hetossa (1.9 ha). Similarly, the study has shown that there was a landholding difference among the weredas. Digelu-Tijo Wereda had the highest average landholding compared to other weredas (Table 3).

5.1.3. Land use patterns

The study has also shown that 77% (n = 138) of the total sampled households do not have land under perennial crops. The remaining 20% (n = 26) have less than 0.5 ha while 3% (n = 6) have 0.5-1.0 ha (Fig. 10). Substantial percentage, which was 40% (n = 72) of the households lease–in agricultural land to increase their cultivated areas while 13% (n = 24) of the respondents lease-out their agricultural land to the others. Payment arrangements could be either rental (27%; n = 49) or crop sharing (12%; n = 21).

Landholding distribution among the wealth groups showed that 25, 23 and 12% of the rich, medium and poor wealth groups have less than 0.50 ha under perennial crops, respectively. Also, 7% of the rich and 3% of the poor groups had 0.5-1.0 ha of land under perennial crops (Annex 1). This shows that there was a significant difference ($P < 0.05$) in having land under perennial crops among the wealth groups.

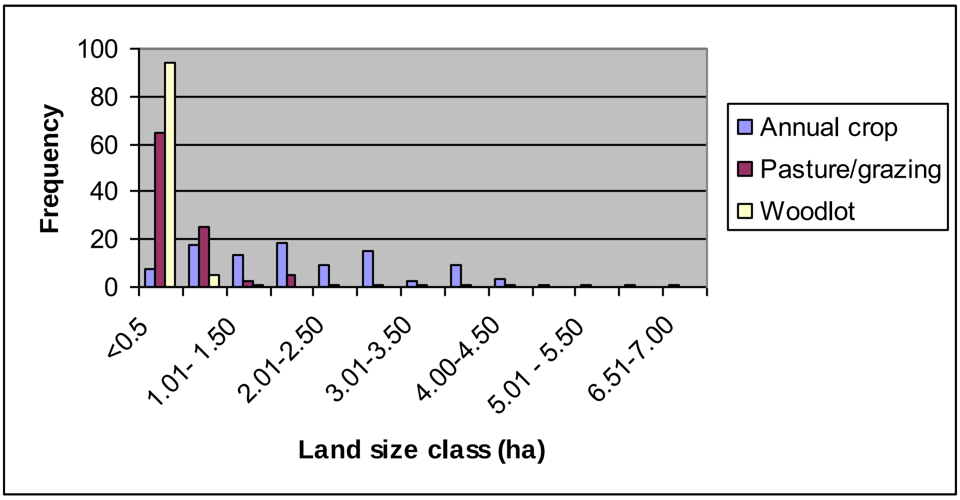

Fig. 10. Land size distribution along land use categories

The households' survey has shown that 67% (n = 121) of the total households leave trees in their farmlands. Comparing this result among the wealth groups, 76% (n = 45) of the rich, 67% (n = 41) of the medium and 58% (n = 35) of the poor leave trees on their farmlands. The study has shown that 82% (n = 148) of the total interviewed households, 88, 79 and 80% of the rich, medium and poor, respectively, practiced agroforestry. ANOVA showed that there are significant differences ($P < 0.05$) among the wealth groups in leaving trees on farmlands and agroforestry practices, which showed that rich group leaves more trees than the medium and the medium more than the poor household groups on different land use systems.

Table 3. Households‘ resources mean in the study weredas

Woreda	Wealth groups	HHs	agricultural prouction income	Total Land Holding	Family size	Oxen	Herds	Number of crop species	Number of species in Home garden
Dodota	Rich	15	15640	4	7	3	30	5	6
	Medium	15	11866	3.1	7	2	32	5	6
	Poor	15	4821	2.3	6	1	5	4	4
	Mean		**10775.7 ± 5491.3**	**3.1 ± 0.9**	**6.7 ± 0.6**	**2.0 ± 1.0**	**22.3 ± 15.0**	**4.7 ± 0.6**	**5.3 ± 1.2**
Lode-Hetossa	Rich	15	28748	2.2	8	3	16	3	6
	medium	15	17867	2	8	3	13	4	4
	Poor	15	7875	1.5	6	1	3	2	4
	Mean		**18163.3 ± 10439.7**	**1.9 ± 0.4**	**7.3 ± 1.2**	**2.3 ± 1.2**	**10.7 ± 6.8**	**3.0 ± 1.0**	**4.7**
Tiyo	Rich	15	43980	4.1	7	6	35	7	5
	medium	15	25407	2.8	7	4	18	6	5
	Poor	15	17294	1.9	5	2	10	5	3
	Mean		**28893.7 ± 13680.4**	**2.9 ± 1.1**	**6.3 ± 1.2**	**4.0 ± 2.0**	**21.0 ± 12.8**	**6.0 ± 1.0**	**4.3 ± 1.2**
Digelu-Tijo	Rich	15	38165	3.9	7	4	38	3	2
	medium	15	26220	3.6	8	2	27	4	1
	Poor	15	13445	1.5	6	1	10	3	1
	Mean		**25943.3 ± 12362.3**	**3.0 ± 1.3**	**7.0 ± 1.0**	**2.3 ± 1.5**	**25.0 ± 14.1**	**3.3 ± 0.6**	**1.3 ± 0.6**
Weredas	Rich		31633.3 ± 12372.2	3.6 ± 0.9	7.3 ± 0.5	4.0 ± 1.4	29.8 + 9.7	4.5 ± 1.9	4.8 ± 1.9
	medium		20340.0 ± 6786.6	2.9 ± 0.7	7.5 ± 0.6	2.8 ± 1.0	22.5 ± 8.6	4.8 ± 1.0	4.0 ± 2.2
	Poor		10858.8 ± 5581.5	1.8 ± 0.4	5.8 ± 0.5	1.3 ± 0.5	7.0 ± 3.6	3.5 ± 1.3	3.0 ± 1.4
	Grand mean		**20944.0 ± 10400.4**	**2.7 ± 0.9**	**6.8 ± 0.9**	**2.7 ± 1.4**	**19.8 ± 11.6**	**4.3 ± 0.7**	**3.9 ± 0.9**

5.1.4 Livestock resources

The study has shown that livestock is very important for the livelihoods of the local community through provision of animal products (meat, milk, hide and egg), draught animals, fertilizer for agricultural land and income generation. Four groups of livestock were recorded in the study area, namely, chicken, goats, sheep, equines (horse, mules and donkeys) and cattle. For the purpose of comparison, livestock populations can be expressed as livestock unit (LU) coefficients that may be used based on weights from FAOSTAT, the global statistical database compiled by the FAO (Chilonda and Otte, 2006). The conversion factors used for the different species are: 1.0 for North American cattle; 0.7 for other cattle; 0.1 for sheep and goats; 0.5 for equines (0.5 donkeys, 0.40 horses and 0.6 mules); 0.01 for chickens.

Mean livestock per household was 5.0 LU[∞] at Dodota, 4.5 LU at Lode-Hetossa, 7.3 LU at Tiyo and 6.5 LU at Digelu-Tijo weredas (Table 4). Rich farm households had more mean livestock (7.3) than medium (6.7) and poor (3.4) households (Table 3). Households in Tiyo Wereda had more average number of livestock unit (7.3) than households in the other weredas while those in Lode-Hetossa had the least (4.5). There were also significant variations among the weredas of which all wealth groups of Tiyo Wereda had more livestock than the other weredas. The mean number of oxen varied from 1.1 to 1.5 LU (Table 4), and no significant difference ($P < 0.05$) existed among weredas in the number of oxen owned by the households.

[∞] Livestock Unit

Table 4. Livestock resources of the households (in livestock unit)

Wealth group	*Chicken*	*Goats&sheep*	*Equines*	*Cattle*	*Oxen*	*Total*
Rich	0.07	1.18	1.08	2.57	1.82	6.7
Medium	0.04	1.33	1.08	1.98	1.68	6.1
Poor	0.02	0.32	0.42	0.58	0.7	2.0
Mean	**0.04**	**0.9**	**0.9**	**1.7**	**1.4**	**5.0**
SD	**0.02**	**0.44**	**0.31**	**0.83**	**0.50**	**2.08**
Rich	0.03	0.42	1	3.27	1.82	6.5
Medium	0.04	0.42	1.08	2.1	1.87	5.5
Poor	0.00	0.15	0.25	0.7	0.47	1.6
Mean	**0.02**	**0.3**	**0.8**	**2.0**	**1.4**	**4.5**
SD	**0.0**	**0.1**	**0.4**	**1.1**	**0.6**	**2.1**
Rich	0.07	0.87	2.08	4.32	1.4	8.7
Medium	0.05	0.65	1.42	3.27	1.63	7.0
Poor	0.03	0.3	1.08	3.27	1.45	6.1
Mean	**0.05**	**0.6**	**1.5**	**3.6**	**1.5**	**7.3**
SD	**0.02**	**0.29**	**0.51**	**0.61**	**0.12**	**1.33**
Rich	0.08	1.02	2.33	3.03	0.89	7.4
Medium	0.04	0.78	2.5	3.5	1.49	8.3
Poor	0.02	0.45	0.58	1.75	0.89	3.7
Mean	**0.05**	**0.8**	**1.8**	**2.8**	**1.1**	**6.5**
SD	**0.03**	**0.29**	**1.06**	**0.91**	**0.35**	**2.44**
Grand mean	**0.04**	**0.66**	**1.24**	**2.53**	**1.34**	**5.81**
SD	**0.02**	**0.29**	**0.56**	**0.85**	**0.40**	**2.00**

* SD = Standard deviation

About 27% (n = 49) of the households did not own sheep and goat. The remaining 42% (n = 75) of households had less than 10 sheep and goats per household. Only 12% (n = 22) of the households had more than 20 sheep and goats. On the other hand, the results have shown that 24% (n = 43) of the surveyed households did not own equines while 63% (n = 114) owned less than 5 equines. The remaining 12% (n = 22) of the households had 5-10 equines per household.

The study has also shown that not all surveyed households from all wealth groups have livestock. As shown in Table 5, 8.5, 10.5, 13.8, 12 and 33.5% of the rich did not own equines, sheep and goats, cattle (excluding oxen), oxen and chicken, respectively. Also 9.8, 20, 11.3, 8 and 37.5% of the medium group did not own equines, sheep and goats, cattle (excluding oxen), oxen and chicken, respectively. This survey has also shown that 49.8, 40.8, 45, 30 and 63.3% of the poor were did not own equines, sheep and goats, cattle (excluding oxen), oxen and chicken, respectively. This means that the rich group had significantly ($P < 0.05$) more livestock followed by the medium and the poor wealth groups.

Twenty three percent (n = 42) of the households did not own cattle and 45% (n = 27) of the poor, 12% (n = 7) of the medium and 14% (n = 8) of the rich wealth groups did not own cattle. Also, only 1% (n = 2) of the households had more than 25 heads of cattle. The remaining households, 39% (n = 71) had less than 5 heads of cattle. There was a significant difference ($P < 0.05$) among the rich, medium and poor wealth groups in the number of cattle of each household. Also, different households owned different number of oxen. The survey had show that 16% (n = 29) of the households did not own oxen while 4% (n = 8) had more than six oxen (Table 5). The overall distribution of the number of oxen among the wealth groups did not show a significant difference ($P < 0.05$).

Table 5. Percentage of households owning livestock resources in the study weredas

Wereda	Wealth group	Equines		Sheep &Goats		Cattle		Oxen		Chicken	
		Yes	No	Yes	No	Yes	No	Yes	No	Yes	No
Dodota	Rich	93	7	79	21	86	14	86	14	80	20
	Medium	87	13	93	7	87	13	100	0	80	20
	Poor	47	53	73	27	40	60	73	27	40	60
Lode-Hetossa	Rich	80	20	93	7	80	20	87	7	33	67
	medium	87	13	60	40	93	7	87	13	53	47
	Poor	20	80	23	77	27	73	47	53	7	93
Tiyo	Rich	100	0	93	7	100	0	100	0	67	33
	medium	100	0	87	13	100	0	100	0	73	27
	Poor	87	13	81	19	80	20	87	13	60	40
Digelu-Tijo	Rich	93	7	93	7	79	21	79	21	86	14
	medium	87	13	80	20	75	25	81	19	44	56
	Poor	47	53	60	40	73	27	73	27	40	60
Mean	Rich	91.5	8.5	89.5	10.5	86.3	13.8	88.0	12.0	66.5	33.5
	Medium	90.3	9.8	80.0	20.0	88.8	11.3	92.0	8.0	62.5	37.5
	Poor	50.3	49.8	59.3	40.8	55.0	45.0	70.0	30.0	36.8	63.3
	G. Mean	**77.3**	**22.7**	**76.3**	**23.8**	**76.7**	**23.3**	**83.3**	**16.7**	**55.3**	**44.8**
	SD	**23.5**	**23.5**	**15.5**	**15.5**	**18.8**	**18.8**	**11.7**	**11.7**	**16.1**	**16.1**

5.2. Composition, Distribution and Production of Agricultural Crops

5.2.1. *Diversity, evenness and distribution of agricultural crops*

A total of 44 species, representing 40 genera and 18 families of cultivated crops were recorded in the study area. Fabaceae had the highest number of species (9) followed by Poaceae (7). Nine of the recorded families had only a single representative species. Two families had four species each while four families had two species each. Asteraceae had five crop species in the assessed sites. The mean number of crop species varied significantly across the weredas and farm households. The number of crop species varied significantly among the weredas. The highest mean number of crop species was recorded in Tiyo Wereda (15 $\pm$ 0.0), while the lowest was recorded in Dodota Wereda (7.0 $\pm$ 0.0) (Table 6). The average number of crops recorded in other weredas was 13.7 $\pm$ 0.6 and 12.7 $\pm$ 2.5 in Lode-Hetossa and Digelu-Tijo, respectively.

The diversity of crop species differed significantly ($P < 0.05$) across all the Kebeles in each wereda (Table 6). Simpson'Index varied from 0.8724 to 0.9672 with mean value of 0.91. Shannon index varied from 1.89 to 2.68 with an average value of 2.50. Evenness index ranged from 0.86 to 0.97. The study sites had high evenness value with a mean of 0.93. This means that evenness in abundance of the species is 93% which showed uniform distribution of crop species. Species evenness was highest for farms in Awash Bishola. Eveness

Index, Simpson's Index and Shannon-Wiener index had highest values in Awash-Bishola Kebele and least standard deviation from the mean which has shown uniform composition of the agricultural crop species.

In overall assessment, the species evenness (0.96) was highest for farms in Dodota Wereda where wheat and barely occupied a significant proportion of the agricultural crops. Shannon's index (2.7) was highest for Tiyo Wereda.

Table 6. Crop species diveristy of the study sites

Wereda	Kebele	HHs	Number of crop species Total	Mean/farm	SD	Simpson Index_ 1-D	Shannon index (H')	Eveness Index (E)
Dodota	Dodota Alem	15	7	3.9	1.4	0.9251	2.61	0.97
	Badosa Betela	15	7	1.7	2	0.8448	1.89	0.94
	Awash Bishola	15	7	4.3	1.1	0.9672	2.68	0.97
	Mean	**15**	**7.0 ± 0.0**	**3.3 ± 1.1**	**1.5**	**0.9 ± 0.1**	**2.4 ± 0.4**	**1.0 ± 0.0**
Lode-Hetossa	Tulu-Jabi	15	14	2.8	1.4	0.9184	2.56	0.92
	Fursa	15	14	3.1	1.8	0.9121	2.52	0.89
	Adamare	15	13	2.9	1.7	0.9108	2.48	0.91
	Mean	**15**	**13.7 ± 0.6**	**2.9 ± 0.2**	**1.6**	**0.9 ± 0.0**	**2.5 ± 0.0**	**0.9 ± 0.0**
Tiyo	Gora - Silingo	15	15	3.9	1.2	0.9275	2.66	0.95
	Burka-Chilalo	15	15	4.3	1.3	0.9278	2.67	0.96
	Tulu-Kuchie	15	15	4.3	1.5	0.9259	2.65	0.95
	Mean	**15**	**15.0 ± 0.0**	**4.2 ± 0.2**	**1.3**	**0.9 ± 0.0**	**2.7 ± 0.0**	**1.0 ± 0.0**
Digelu-Tijo	Sagure Mole	15	15	3.8	1.4	0.9246	2.64	0.93
	Kechema -Murkicha	15	10	1.9	1.8	0.8724	2.15	0.86
	Shaldo-Jigessa	15	13	2.4	1.6	0.9059	2.45	0.89
	Mean	**15**	**12.7 ± 2.5**	**2.7 ± 1.0**	**1.6**	**0.9 ± 0.0**	**2.4 ± 0.2**	**0.9 ± 0.0**
	Grand Mean		**12.1 ± 0.8**	**3.3 ± 0.6**	**1.5**	**0.9 ± 0.09**	**2.5 ± 0.2**	**0.9 ± 0.0**

There was a significant variation in crop species distribution along the study sites (Annex 2). Wheat and barley were recorded in all the study weredas and they occupied the highest proportion of agricultural land, 213 and 85 ha, respectively (Fig. 11) and contributed the high proportion to the agricultural crop production of the households (wheat 49% and barley 20%).

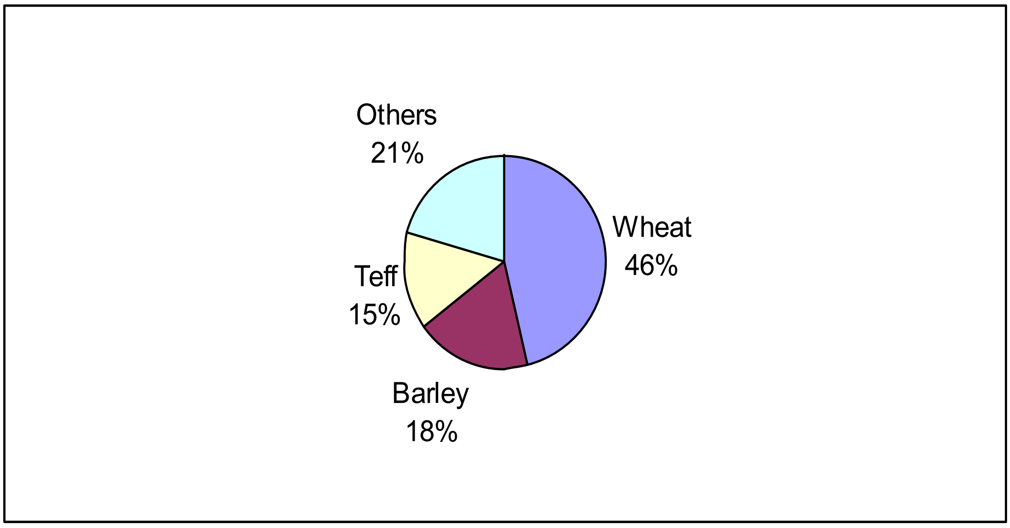

Fig. 11. Relative land sizes of agricultural crops

A total of eight functional groups of crops were recorded from the study area (Fig. 12). Pulses had the highest percentage of species (21%) followed by fruits (18%. The cereals had a share of 14% followed by oil seeds and vegetables which had 11% species, each. The stimulants had the lowest percentage (7%) while roots and tubers and speces and condiments had 9% each of the recorded species of the agricultural crops.

Cereal crops were grown in all kebeles of the study sites while the distributions of pulses depend on the climatic zonation of the area. Most of the pulses were grown in the middle altitudes and the highlands. The distribution of fruit trees depends mainly on the availability of irrigation water or high rainfall. Roots and tubers were not common in most kebeles, except onion which was grown at mid altitudes as a cash crop. Especially, Lode-Hetossa is known for its high production of onion which is exported to different parts of the country. Other vegetables are mainly grown during the rainy season for household consumption and income generation

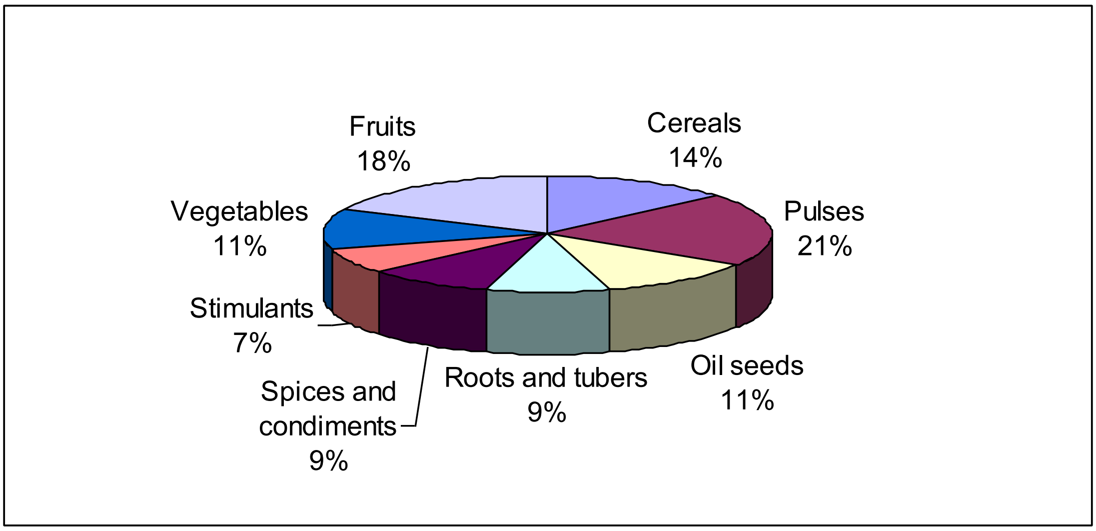

Fig. 12. Proportional distribution of functional crop species

The occurrence of agricultural crop species varied significantly along the farms. Wheat and barley farms occurred in 83% and 56% of the total farms, respectively. On the other hand, 17 crop species occurred in less than 1% of the farms. Fig. 13 shows the number of farms in which the species occur.

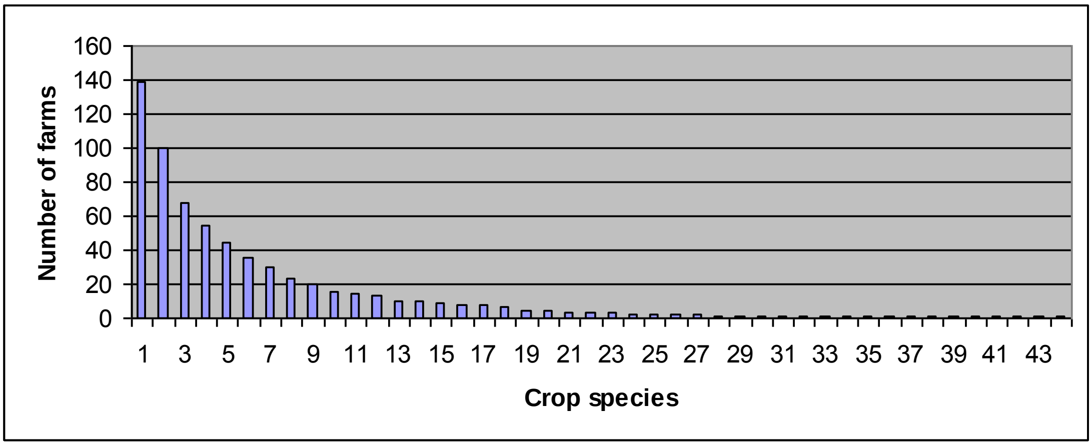

Fig. 13 Frequency of occurrence of cop species across the farms

Key:

1) Triticum aestivum; 2) Hordeum vulgare; 3) Eragrotis tef; 4) Vicia faba; 5) Allium sativum; 6) Zea mays 7) Pisum sativum; 8) Linum usitatissimum 9) Allium cepa; 10) Phaseolus vulgaris; 11) Sorghum bicolor; 12) Solanum tuberosum; 13) Ruta chalepensis; 14) Brassica oleracea; 15) Coffea arabica; 16) Malus sylvestris; 17) Ensete ventricosum; 18) Rhamnus prinoides; 19) Casimiroa edulis; 20) Brassica carinata; 21) Citrus aurantifolia; 22) Mangifera indica; 23) Citrus sinensis; 24) Cicer arietinum; 25) Lathyrus sativus; 26) Triticum dicoccon; 27) Psidium guajava; 28) Coccinia abyssinica;29) Persea americana; 30) Musa x paradisiacal; 31) Manihot esculenta; 32) Catha edulis; 33) Vigna unguiculata; 34) Ricinus communis; 35) Lens culinars; 36) Guizotia abyssinica; 37) Carica papaya; 38) Cajanus cajan; 39) Saccharum officinarum; 40) Rosamarinus officinalis; 41) Glycine max; 42) Carthamus tinctorius; 43) Nicotiana tobacum; and *44) Lycopersicon esculentum.*

5.2.2. Similarity of sites in composition of agricultural crop species

The study revealed that there were highest similarities in the composition of agricultural crops species among the kebeles of the same wereda. Jaccard‘s similarity index was 1.0 for kebeles in Dodota Wereda as well as for kebeles found in Digelu-Tijo Wereda. The least similarities were recorded between Burka Chilalo Kebele of Tiyo Wereda and three kebeles of the Dodota Wereda of which only about 30% were recorded in both weredas. In most cases, dissimilarity increased with the distance of one wereda from the other (Table 7) and differences in elevation. For example, Burka

Chilalo is located at the foot of Mt. Chilalo (2572 m) while Dodota Wereda kebeles are located at lower altitudes (ca.1441-1759 m).

Table 7. Jaccard's Similarity Index of the number of agricultural crop species among the kebeles of the study sites

Kebeles	Dodota Alem	B/Betela	Awash Bishola	Tulu Jabi	Fursa	Adamare	Gora silingo	Burka Chilalo	Tulu Kuchie	Sagure Mole	Kechema Murkicha	Shaldo Jigessa
Dodota Alem	1.00											
B/Betela	1.00	1.00										
Awash Bishola	1.00	1.00	1.00									
Tulu jabi	0.50	0.50	0.50	1.00								
Fursa	0.57	0.57	0.57	0.44	1.00							
Adamare	0.57	0.57	0.57	0.63	0.71	1.00						
Gora Silingo	0.57	0.57	0.57	0.63	0.33	0.50	1.00					
Burka Chilalo	0.30	0.30	0.30	0.36	0.27	0.40	0.40	1.00				
Tulu kuchie	0.56	0.56	0.56	0.45	0.36	0.36	0.67	0.42	1.00			
Sagure Mole	0.38	0.38	0.38	0.63	0.33	0.33	0.50	0.40	0.50	1.00		
Kechema Murkicha	0.38	0.38	0.38	0.63	0.33	0.33	0.50	0.40	0.50	1.00	1.00	
Shaldo Jigessa	0.33	0.33	0.33	0.56	0.30	0.44	0.44	0.67	0.45	0.63	0.63	1.00

5.2.3. Income and expenditure in the process of agricultural crops production

5.2.3.1. Income from agricultural crops

About 457 ha of farms were put under crop production by the total sampled households in the study year and 8,310 quintals of different agricultural crops (cereals, oilseeds, pulses) were produced, generating the value of about Birr 3.4 million. The yield data was obtained for sixteen annual crop species of which wheat has the highest share of total production and income generation. About 49% of the income of the agricultural production of the households comes from wheat production (Table 8).

Table 8. Land areascovered and production of the 16 major crops in 2008

No.	Crop species	land area (ha)	Total production(quintal[∞])	Total value (Birr)	Relative value (%)
1	*Triticum aestivum*	213.5	4,132.50	1,689,747.00	49.3
2	*Hordeum vulgare*	85.0	1,523.00	688,055.00	20.1
3	*Eragrostis tef*	61.4	457.50	316,100.00	9.2
4	*Vicia faba*	21.1	363.50	200,400.00	5.9
5	*Allium sativum*	10.0	776.00	115,485.00	3.4
6	*Linum usitatissimum*	12.3	127.00	96,080.00	2.8
7	*Pisum sativum*	9.6	140.50	87,250.00	2.5
8	*Zea mays*	18.2	243.00	59,510.00	1.7
9	*Phaseolus vulgaris*	12.8	105.50	45,700.00	1.3
10	*Solanum tuberosum*	3.6	281.00	42,513.00	1.2
11	*Brassica carinata*	2.8	40.00	28,950.00	0.8
12	*Sorghum bicolor*	3.3	71.00	27,600.00	0.8
13	*Cicer arietinum*	1.1	16.00	12,800.00	0.4
14	*Triticum dicoccon*	0.8	20.00	8,000.00	0.2
15	*Guizotia abyssinica*	0.5	5.00	3,500.00	0.1
16	*Lathyrus sativus*	0.8	9.00	2,700.00	0.1
	Total	456.8	8,310.50	3,424,390.00	100.0

The agricultural production of the households significantly varied among weredas and the economic groups. The study showed that 67, 93, 87, and 71% of the rich wealth groups in Dodota, Lode-Hetossa, Tiyo and Digelu-Tijo weredas, respectively, could produce enough food for annual consumption for their families. The lowest percentage was found in Dodota followed by Digelu-Tijo Wereda (Fig. 14). According to the discussions made with the local

[∞] Quintal = 100 kg

communities, this may be attributed to shortage of rainfall in Dodota Wereda and water logging in Digelu - Tijo Wereda.

Household interview showed that only 55% (n = 99) of all the sampled households produced enough food for annual consumption of the family. Comparing this total result among the wealth groups showed that 80% of the rich, 53% of the medium and 33% of the poor wealth group produced enough food from own farms. The results have also revealed that 28% of the respondents produced only enough for less than six months owing the shortage of agricultural land, shortage of agricultural inputs and bad weather. Food gaps were managed by the households through sales of livestock (11%), sales of family labor (2%), remittance (2%), aid from Governement and NGOs (6%), borrowing from friends and relatives (5%), sales of forest products (1%) and combination of all (10%). The rich filled the food gaps from sales of livestock (except for Dodota Wereda) while the medium and the poor wealth group used different sources to cover the food gap. It was only the poor who earn income from the sales of family labor. There were differences in gap filling mechanisms among the wealth groups.

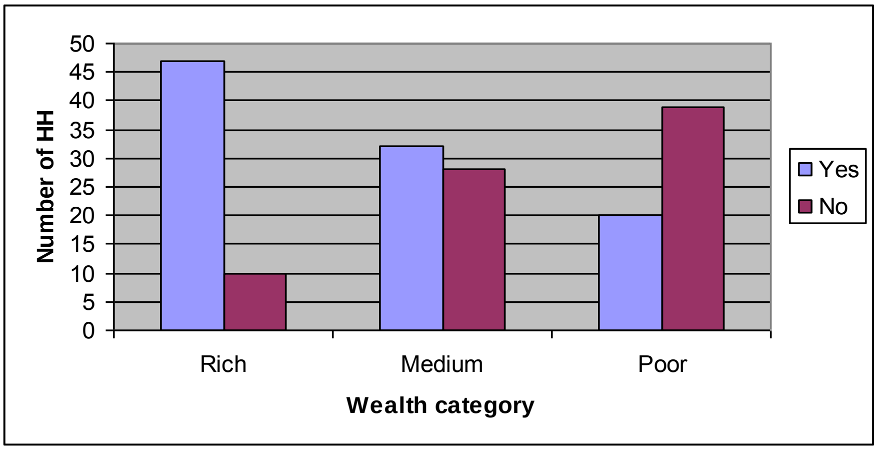

Fig. 14. Annual food self sufficiency of the households

5.2.3.2 Costs of agricultural crops production

The results reaveled that the costs of production varied significantly among weredas based on the distance from the market, land productivity, crop species and availability of agricultural land. Based on these criteria the highest cost of production was paid in Lode-Hetossa Wereda where onion and wheat are the most important crops for income generation. The highest cost of agricultural production is paid for land lease (ca. Birr 8000 ha^{-1} $year^{-1}$). The lowest cost of land lease Birr 2000 ha^{-1} $year^{-1}$ was paid in Dodota and Digelu-Tijo weredas (Fig. 15).

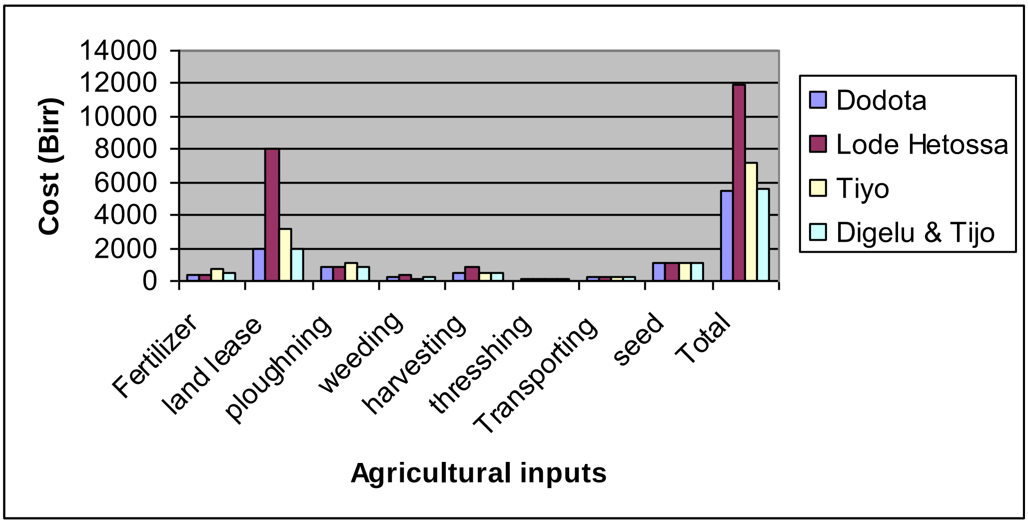

Fig. 15. Average costs (in Birr) for agricultural inputs in different weredas

5.2.3.3 Income of households from different activities

Each household was engaged in different activities to generate income for livelihoods of the family. Income from agricultural crop production was positive only for rich households. It was negative for the medium and the poor households. Livestock rearing is the main source of income followed by off-farm employment. The rich households generated ca. 16% of their annual income from agricultural crops, 41% from sales of livestock, 18% from off-farm employment, 11% from petty trade and 9% from sales of forest products. The income of medium and poor wealth groups had followed the same pattern (Table 9). Most of the households in the rich group generated higher amount of annual income followed by households in the medium wealth group. The poor had the lowest income from all sources of income except forest products.

Table 9 Sources and average annual net income (in Birr) of the households

Sources	**Wealth group**					
	Rich	**%**	**Medium**	**%**	**Poor**	**%**
Agricultural crops	1373	16	-1599	-34	-4271	-144
Livestock	3407	41	2541	54	1250	42
Forest products	712	9	295	6	317	11
Petty-trade	881	11	377	8	233	8
Off-farm employment	1475	18	1361	29	1117	38
Remittance	525	6	164	3	50	2
Total	**8,373**	**100**	**3,139**	**100**	**-1304**	**100**

The study showed that 32% (n = 57) of the surveyed households, of which 17% of the rich, 21% of the medium and 55% of the poor, were not getting income from sales of livestock. According to this study the mean annual income from sales of livestock was Birr 5000, 2000, 800 for rich, medium and poor, respectively (Fig. 16).

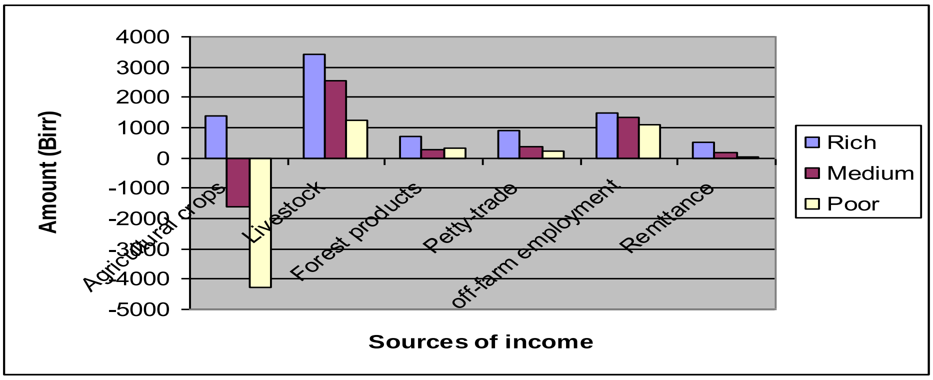

Fig. 16. Sources and average income (Birr) by wealth groups

5.2.3.4. Costs and benefits of agricultural crop production

The total net income of the households from agricultural crop production varied among weredas. The highest annual income from agricultural crops was recorded for Digelu-Tijo Wereda (Birr 107/hh) and the lowest was for Lode-Hetossa, which was negative (Birr 102/hh). The lowest income for Lode-Hetossa was attributed to the highest land lease (Birr 8,000/ha). The net income of Dodota and Lode-Hetossa was negative (Table 10).

Table 10 Average annual income and cost of the households from agricultural crop production (in Birr)

Wereda	Land area (ha)	Total Income	Total cost	Net income	Net income/ha	Income /HH	B/C
Dodota	66.87	306,540	365,110	(58,570)	(876)	(19)	0.84
Lode-Hetossa	109.68	810,099	1,313,747	(503,648)	(4592)	(102)	0.62
Tiyo	129.74	1,299,200	935,166	364,034	2806	62	1.39
Digelu-Tijo	90.88	949,340	510,200	439,140	4832	107	1.86
Total	397.17	3,365,179	3,004,591	360,588	908	20	1.12
Mean	99.3	841,294.75	781,055.75	60,239.00	607	12.0	1.08
SD	26.8	411,617.46	429,683.47	435,102.09	2,170.10	92.2	0.6

* Numbers in brackets indicate negative values

The overall income and cost ratio for the study area showed 12% profit from agricultural crops production. However, this profit was not evenly distributed among the weredas. Households of the two weredas, Dodota and Lode-Hetossa, registered loss from crop production, while the highest profit was recorded for Digelu-Tijo (86%) and Tiyo (39%). However, in this calculations o fprofits, the effect of the production of agricultural crops on the environment and degradation of the agroecosystems were not considered.

5.2.4. Trends of agricultural crops production

The annual production of agricultural crops significantly varied for different crops and had similar trend for each crop species. Sixty six percent (n = 118) of the respondents said that crop production over the last five years has been increasing while 33% (n = 41) said it has been decreasing (Fig. 17). However, the data collected on five years production of the households did not show continued increasing trend. Wheat has shown an increase in trend compared to the previous years while a decreasing trend was observed in 2007. The production situation showed similar trends for other agricultural crops, including wheat. The trends of agricultural crop production did not show a significant variation ($P < 0.05$) for the recorded years.

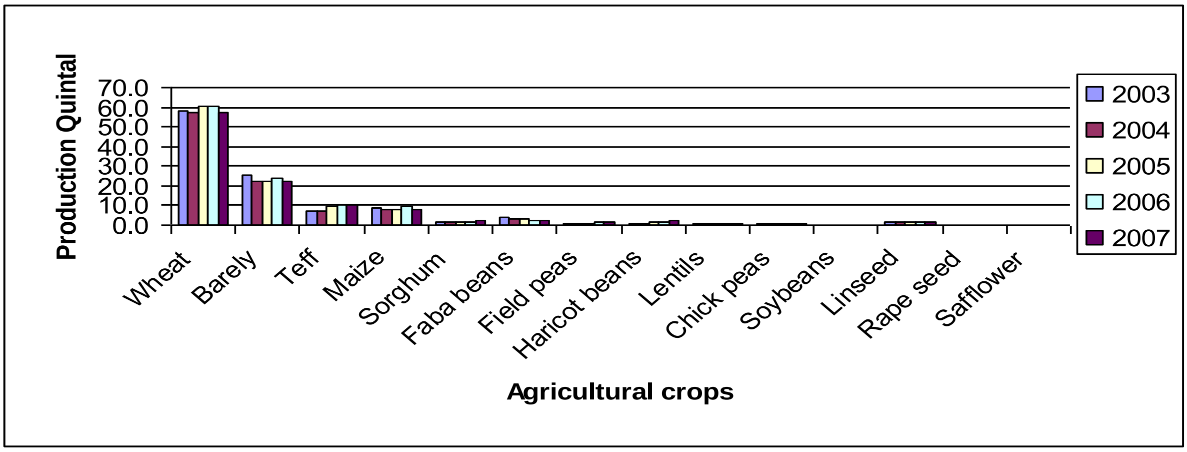

Fig. 17. Trends of average agricultural crops production of the households (2003-2007)

5.3. Composition and Distribution of Tree and Shrub Species in the Study Sites

5.3.1 Diversity of tree and shrub species

A total of 90 species representing 75 genera and 48 families of trees and shrubs were recorded in homestead, on farm and pasturelands of the study sites (Annex 3). Fabaceae has the highest number of genera (n = 20) followed by Rosaceae (n = 4). From the recorded Families, 31 of them were represented by only one species each. *Acacia* was one of the genera, which had the highest number of species (n = 11) followed by *Citrus, Eucalyptus*, *Euphorbia, Myrsine* and *Ficus,* which had two species each. The remaining 69 genera were represented by a single species each. The frequency of occurrence of these species varied across the study areas and *Eucalyptus globulus* occurred in more than 63% of the farms (Fig. 18). It is followed by *Croton macrostachyus* (39%), *Olea europaea* subsp. *cuspidata* (32%), and *Schinus molle* (31%). More than 80 species only occurred in less than 5% of the farmlands. From these recorded species, about 21 were exotic while the remaining 69 were indigenous species.

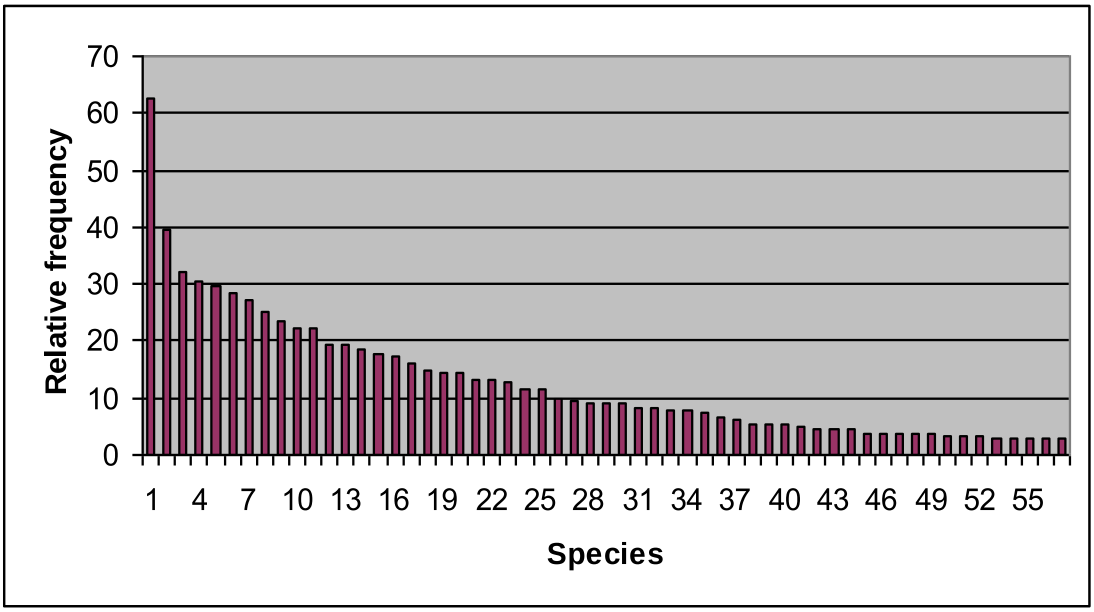

Fig. 18. Relative frequencies of tree and shrub species (having 3% and above relative frequency) across the study sites.

Key:

1) *Eucalyptus globulus;* 2) *Croton macrostachyus;* 3) *Olea europaea* subsp. *cuspidata*; 4) *Schinus molle;* 5) *Acacia abyssinica;* 6) *Melia azedarach;* 7) *Juniperus procera;* 8) *Acacia etbaica;* 9) *Hagenia abyssinica;* 10) *Acacia tortilis;* 11) *Cordia africana;* 12) *Calpurnia aurea:* 13) *Justicia schimperiana;* 14) *Dovyalis abyssinica;* 15) *Podocarpus falcatus;* 16) *Ficus sur;* 17) *Sesbania sesban;* 18) *Acacia saligna;* 19) *Balanites aegyptiaca;* 20) *Ficus vasta;* 21) *Carrisa spinarum;* 22) *Casuarina cunninghamiana;* 23) *Acacia albida;* 24) *Acacia seyal;* 25) *Cupressus lusitanica;* 26) *Maytenus undata*; 27) *Vernonia amygdalina;* 28) *Rosa abyssinica;* 29) *Acacia senegal*; 30) *Ziziphus mauritiana;* 31) *Erica arborea;* 32) *Cytisus palmensis;* 33) *Hypericum revolutum;* 34) *Acacia nilotica;* 35) *Buddleja polystachya;* 36) *Discopodium penninervum;* 37) *Eucalyptus camaldulensis;* 38) *Euclea racemosa* subsp. *schimperi;* 39) *Rubus apetalus;* 40) *Maesa lanceolata;* 41) *Coffea arabica;* 42. *Malus sylvestris;* 43) *Prunus africana;* 44) *Myrsine melanophloeos;* 45) *Sclerocarya birrea*; 46) *Rhamnus prinoides*; 47) *Dichrostachys cinerea*; 48) *Ehretia cymosa;* 49) *Schefflera volkensii*; 50) *Pterolobium stellatum;* 51) *Ekebergia capensis*; 52) *Phytolacca dodecandra*; 53) *Acokanthera schimperi*; 54) *Casimiroa edulis;* 55) *Leucaena leucocephala;* and *56*) *Premna schimperi.*

The number of tree and shrub species significantly differed among the kebeles ranging from seven in Kechema Murkicha and Sagure Mole kebeles of Digelu-Tijo Wereda to 49 species in Burka Chilalo of Tiyo Wereda (Table 11). The mean number of tree and shrub species among the weredas varied from 10.3 ± 1.7 in Dodota to 2.8 ± 1.8 in Digelu-Tijo Weredas. The highest number of tree and shrub species was recorded at the highest altitude (Burka Chilalo Kebele n = 49) and the next higher number of species was recorded at the (Awash Bishola Kebele and Tulu Jabi Kebeles n = 40).

Table 11 Richness, diversity and eveness indices of tree and shrub species

Woreda	Kebele	Richness of treeand shrub species			Shannon's Index (H')	Evenness (E)
		Total	Mean	SD		
Dodota	Dodota Alem	33	10.1	5.06	3.02	0.73
	B/Betela	26	8.8	2.04	2.78	0.67
	Awash Bishola	40	12.1	4.7	3.06	0.79
	Mean	**33.0 ± 7.0**	**10.3 ± 1.7**	**3.9**	**3.0 ± 0.2**	**0.7 ± 0.1**
Lode-Hetossa	Tulu jabi	40	10.5	3.31	2.95	0.73
	Fursa	37	10.9	4.44	3.21	0.69
	Adamare	26	7.5	1.84	3.32	0.71
	Mean	**34.3 ± 7.4**	**9.6 ± 1.9**	**3.2**	**3.2 ± 0.2**	**0.7 ± 0**
Tiyo	Gora silingo	21	3.5	2	2.84	0.78
	Burka chilalo	49	16.9	4.76	3.45	0.68
	Tulu Kuchie	26	9.6	3.71	2.37	0.71
	Mean	**32 ±14.9**	**10 ± 6.7**	**3.5**	**2.9 ± 0.5**	**0.7 ± 0.1**
Digelu-Tijo	Sagure Mole	7	1.5	1.12	1.52	0.65
	Kechema Murkicha	7	2	1.25	2.43	0.67
	Shaldo Jiggessa	19	4.8	2.11	1.25	0.5
	Mean	**11.0 ± 6.9**	**2.8 ± 1.8**	**1.5**	**1.7 ± 0.6**	**0.6 ± 0.1**

Species evenness varied between 0.5 and 0.79. The mean value of measure of evenness (E) was 0.68. This means that the relative homogeneity of the species in the samples was 68%. This also means that the relative abundance of the different species in the sample is even. Species evenness was highest at Awash Bishola Kebele (0.79), which means that the commonly occurring species are evenly distributed along the studied kebeles. Shannon value ranged from a minimum of 1.25 at Shaldo Jigessa to a maximum of 3.45 at Burka Chilalo Kebele. Shannon's index of diversity showed a total mean value of 2.68 at the study sites. Both species diversity and evenness were the lowest at Shaldo Jigessa Kebele where *Eucalyptus globulus* was dominant and a few number of tree and shrub species were recorded.

5.3.2 Occurrence of tree and shrub species in the study weredas

Occurrence of tree and shrub species varied along the weredas (Fig. 19) and ranged from 21 in Digelu-Tijo to 58 tree and shrub species in Lode-Hetossa weredas. The findings showed that 9% (n = 8) species, namely *Acacia abyssinica, Acacia saligna, Casuarina cunninghamiana, Cordia africana, Olea europaea* subsp. *cuspidata, Justicia schimperiana, Sesbania sesban* and *Ficus sur* were recorded in all the weredas. Among these species, five were indigenous while the remaining three were exotic. The remaining species were distributed along the weredas of which 18, 26, and 47% were found in 3, 2, and 1 weredas, respectively (Annex 4).

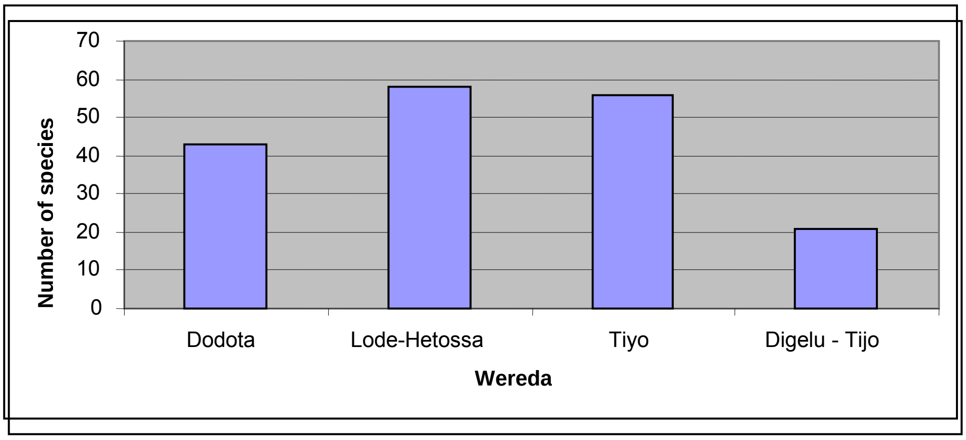

Fig. 19. Number of tree and shrub species recorded in the study weredas

5.3.3. Classification of tree and shrub species

Four vegetation types (Fig. 20) were identified using cluster analysis. The analysis was based on occurrence data of the tree and shrub species in the farms (Table 12).

Group 1 comprised 27 highland species. *Eucalyptus globulus* and *Malus sylvestris* were the only exotic species associated with this group. The main tree and shrub species found in this group were: *Eucalyptus globulus, Juniperus procera, Olea europaea* subsp. *cuspidata, Hagenia abyssinica* and *Podocarpus falcatus.*

Group 2 comprised11 tree and shrub species. The main species found in this group were mainly, grown in the middle altitudes. All of these associated tree and shrub species contain indigenous species having different uses. The tree and shrub species in this group include: *Croton macrostachyus*, *Acacia abyssinica*, *Calpurnia aurea*, *Cordia africana*, *Justicia schimperiana* and some other species.

Group 3 comprised 18 tree and shrub species that were mainly found in the lowlands. It was comprised most of the *Acacia* and associated species. These species included: *Acacia etbaica*, *Acacia tortilis*, *Schinus molle*, *Melia azedarach*, *Balanites aegyptiaca* and *Acacia seyal*.

Group 4 comprised 34 associated species of indigenous (23) and exotic (11) species. The exotic species are mainly planted around the houses for windbreak, ornamental, food and income generation. Most of the indeginous tree and shrub species were found on the degraded lands and along the vallyes. This groupwas comprised of *Ficus sur, Ficus vasta*, *Casimiroa edulis*, *Dodonaea angustifolia*, *Euclea racemosa* subsp. *schimperi*, *Grevillea robusta* and *Celtis africana*.

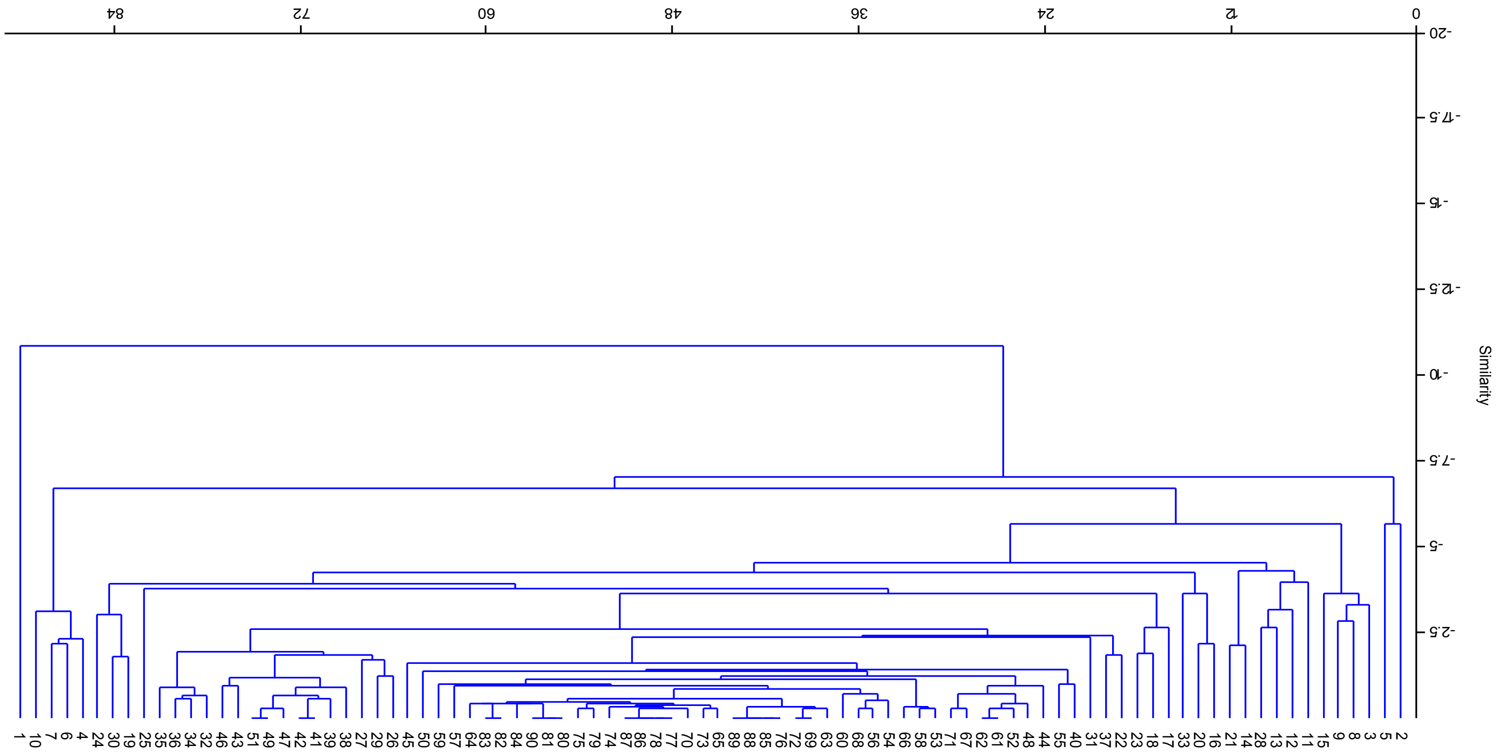

Fig. 20. Classification of tree and shrub species into vegetation types

Table 12 List of clustered associate species

Cluster No.	No. of species	Associated species in the cluster
1	27	*Eucalyptus globulus, Juniperus procera, Olea europaea* subsp. *cuspidata, Hagenia abyssinica, Podocarpus falcatus, Erica arborea, Hypericum revolutum, Discopodium penninervium, Buddleja polystachya, Maytenus undata, Rosa abyssinica, Maesa lanceolata, Malus sylvestris, Myrsine melanophloeos, Rubus apetalus, Schefflera volkensii, Ekebergia capensis, Sclerocarya birrea, Prunus africana, Rhamnus prinoides, Euphorbia candelabrum, Bersama abyssinica, Canthium schimperanum, Lippia adoensis, Acanthus sennii, Myrsine africana*
2	11	*Croton macrostachyus, Acacia abyssinica, Cordia africana, Calpurnia aurea, Justicia schimperiana, Dovyalis abyssinica, Carrisa spinarum, Vernonia amygdalina, Acacia mellifera, Coffea arabica and Phytolacca dodecandara*
3	18	*Schinus molle, Acacia etbaica, Acacia gerrardii, Melia azedarach, Acacia tortilis, Ficus sur, Sesbania sesban, Acacia saligna, Balanites aegyptiaca, Ficus vasta, Casuarina cunninghamiana, Acacia albida, Acacia seyal, Cupressus lusitanica, Ziziphus mauritiana, Cytisus palmensis, Acacia nilotica and Eucalyptus camaldulensis*
4	34	*Acacia senegal, Ehretia cymosa, Dichrostachys cinerea, Pterolobium stellatum, Acokanthera schimperi, Casimiroa edulis, Leucaena leucocephala, Carica papaya, Celtis africana, Dodonaea angustifolia, Grevillea robusta, Hallea rubrostipulata, Premna schimperi, Citrus aurantifolia, Citrus sinensis, Euclea racemosa* subsp. *schimperi, Grewia trichocarpa, Mangifera indica, Dombeya torrida, Dracaena afromontana, Ocimum gratissimum, Phoenix reclinata, Psidium guajava, Agarista salicifolia, Arundinaria alpina, Catha edulis, Delonix regia, Erythrina brucei, Euphorbia tirucalli, Moringa stenopetala, Myrica salicifolia, Persea americana, Pittosporm viridiflorum and Spathodea campanulata* subsp. *nilotica*

5.3.4 Similarity in composition of tree and shrub species across the sites

There was high similarity among the kebeles found within the weredas of KOLLA and DEGA traditional agroecological zones. The highest similarity was recorded between Shaldo Jigessa and Sagure Mole kebeles sharing 92% of the species. The least similarities were found among the kebeles found in Dodota and Digelu-Tijo weredas (0-12%). Altitude and geographical distance have effects on the similarity of tree and shrub species across the sites. Similarity decreased with increasing distance and elevation difference. The similarity between sites varied from 0 to 92% (Table 13).

Table 13. Jaccard's Similarity Index of tree and shrub species along the study kebeles

	Study Kebeles											
Kebeles	Dodota-Alem	B. Betela	A/Bishola	T/Jabi	Fursa	Adamare	G/Silingo	B/Chilalo	T/Kuchie	S/Mole	K/Murkicha	S/jigesa
Dodota-Alem	1.00											
B/Betela	0.81	1.00										
A/Bishola	0.61	0.54	1.00									
Tulu Jabi	0.49	0.49	0.32	1.00								
Fursa	0.20	0.40	0.07	0.46	1.00							
Adamare	0.03	0.05	0.00	0.17	0.46	1.00						
G/silingo	0.10	0.08	0.05	0.18	0.60	0.62	1.00					
B/Chilalo	0.21	0.18	0.19	0.10	0.00	0.35	0.39	1.00				
T/Kuchie	0.04	0.10	0.03	0.29	0.55	0.43	0.55	0.15	1.00			
S/ Mole	0.06	0.07	0.07	0.05	0.31	0.36	0.47	0.36	0.68	1.00		
K/ Murkicha	0.07	0.12	0.01	0.04	0.21	0.48	0.46	0.44	0.53	0.76	1.00	
S/Jigessa	0.00	0.02	0.01	0.09	0.37	0.38	0.48	0.33	0.67	0.92	0.68	1.00

5.3.5. *Ethnobotanical knowledge of the local communities*

5.3.5.1. Use-categories of the tree and shrub species

From the recorded tree and shrub species in the study sites, 64 of them were grouped into thirteen use-categories by the respondents. The number of species in each category ranged from 1 to 53. These categories were: Construction (44), fuelwood (50), nitrogen fixing (47), conservation (53), income generation (42), shade (38), fodder (35), windbreak (35), medicine for humans and animals (24), ornamental (18), food (15), farm implements (2) and live fence (1) (Fig. 21).

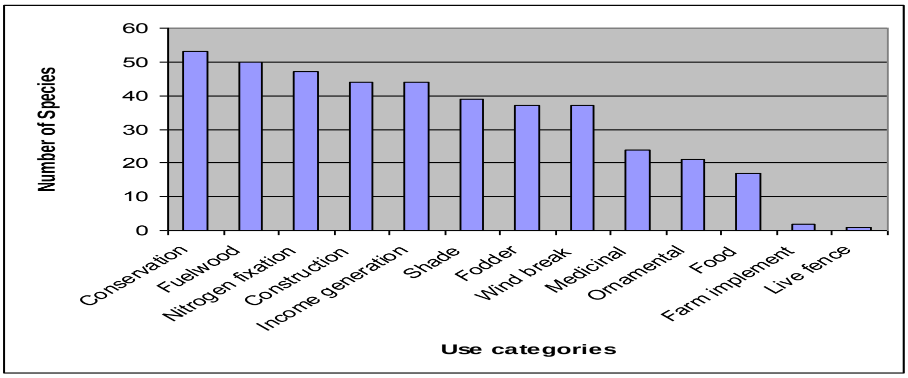

Fig. 21. Number of species reported by use-category for the study sites

5.3.5.2. Relative importance and use-values of tree and shrub species

The relative importance of 64 tree and shrub species were ranked under eleven major use-categories based on the valuations of the interviewees (Annex 5). Most of these listed tree and shrub species have multipurposes. From the main uses of the tree and shrub species, it was found that *Eucalyptus globulus* had 11 uses of which 5 uses had the highest relative importance value to the households. *Eucalyptus globulus* had the highest relative importance for construction (37.8), fuelwood (35.6), income generation

(30.0), windbreak (22.2), conservation (13.3), *Melia azedarach* for medicine (12.2), *Sesbania sesban* for animal feed (7.8) and *Malus sylvestris* for food (3.9) (Fig. 22). The other species, which had the highest relative importances were *Acacia tortilis* for shade, *Acacia etbaica* for nitrogen fixing, and *Acacia albida* for ornamental uses. Both indigenous (44) and exotic (20) species were included in the list.

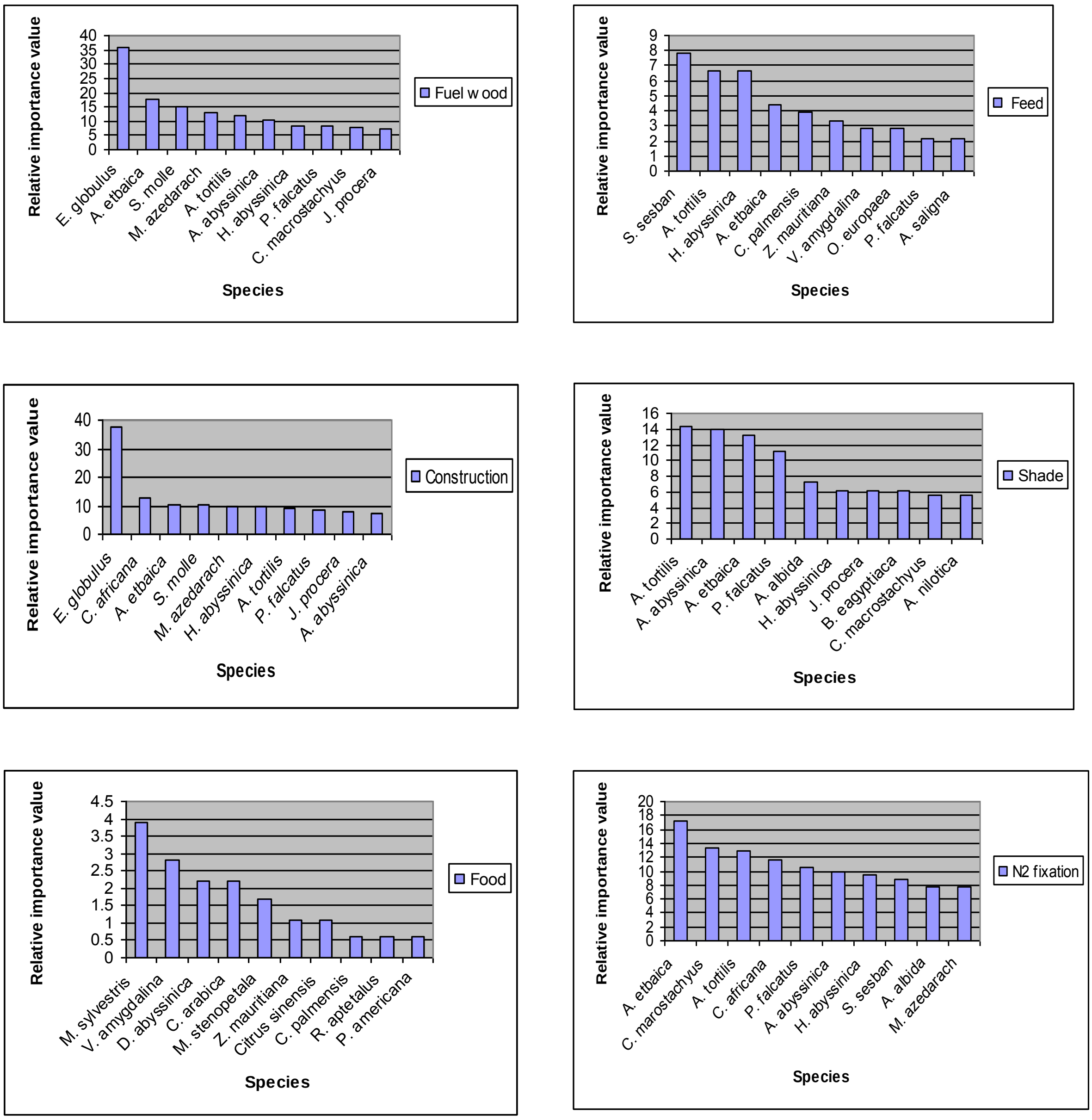

Fig. 22. Relative importance value of ten important tree and shrub species for six use categories

The number of tree and shrub species used for various purposes varied in the study weredas, of which the use-values of 39, 34, 28 and 7 species were recorded for Tiyo, Dodota, Lode-Hetossa and Digelu-Tijo Weredas, respectively. The results showed that, in Tiyo Wereda, *Eucalyptus globulus* and *Hagenia abyssinica* had the highest use-values (2.47), while *Acacia tortilis* had the highest use-value (2.50) in Dodota Wereda, *Cordia africana* (2.51) in Lode-Hetossa and *E. globulus* (2.71) in Digelu-Tijo weredas (Annex 6). This implies that the importance of tree and shrub species varied at different agroecological zones.

The highest proportion (76% n = 137) of the respondents said that plants are the main sources of traditional medicine. According to this finding, 13 (n = 23) and 16% (n = 28) of the respondents said women and men, respectively, were responsible for the collection of medicinal plants. But, 59% (n = 108) said both of them are responsible for collection of medicinal plants. About 50% (n = 89) said that the knowledge on medicinal plants has been inherited from parents while 31% (n = 56) said the knowledge on traditional medicinal plants was aquired from parents and through informal training by elderly people on medicinal plants.

5.4 Alternative Technologies for Sustainable Agricultural Production and Ecosystem Conservation

The results of the different parameters showed that out of the low-input variables, included crop diversity, tree diversity, land size, family size, number of livestock and farm size significantly differred among the wealth groups (Table 14).

Table 14 Comparisons of mean values of key resources among the three wealth groups

Key resources	Poor HH (n = 60)		Medium HH (n = 60)		Rich HH (n = 60)		ANOVA
	mean	SD	mean	SD	mean	SD	*P*
Landholding	1.8	0.6	2.8	1.1	3.5	0.9	*
Family size	5.7	1.6	7.3	1.9	7.3	1.1	*
Oxen	1.3	0.6	2.6	1	3.9	1.7	NS
Other animals	6.7	4.4	22.3	15.4	29.6	12.5	*
Crop diversity	3.2	1.5	4.7	1.7	4.6	2.4	*
Tree and shrub species diversity	3.2	1.8	4	2.7	4.7	2.6	*

- Significant at P <0.05; NS = not significant

5.4.1. Diversification of agricultural crop species

The average number of crops recorded ranged from 2 to 7 species. The number of crop species grown by the households varied among weredas and wealth groups. Tiyo Wereda had the highest average number of crops while Lode-Hetossa Wereda had the least average number of crops. The poor households in all weredas used the lowest number of crop species than the rich and medium wealth group households. The rich used more average number of crop species than the medium wealth group in Dodota and

Tiyo while the medium households used more number of crop species in the other two weredas. It was found that there was a statistically siginificat (P < 0.05) difference among the households in the crop diversity that own and use diversified agricultural crop species.

5.4.2. Crop rotation

There was a significant difference (P < 0.05) in the use of crop rotation among the three wealth groups. Ninety two percent (n = 165) of the total households (n = 180) used crop rotation, which included 93 (n = 55), 97 (n = 59) and 86% (n = 51) of the rich, medium and of the poor wealth groups, respectively.

The farmers in the study weredas used different crop species in rotation. Most of the farmers (76%) in Dodota used wheat in rotation with TEF. The most used crop species used in rotation in Lode-Hetossa Wereda were wheat being rotated with barley (38%). Fifty one percent and 42% of the respondents in Tiyo and Digelu-Tijo, respectively, were using wheat in rotation with faba beans, respectively. Haricot bean and soybeans were the only legumes used for crop rotation in the lowlands whereas faba beans, field peas, grasspea, chickpeas and cowpeas were the legume species used for crop rotation with cereal crop species in the highlands (Fig. 23).

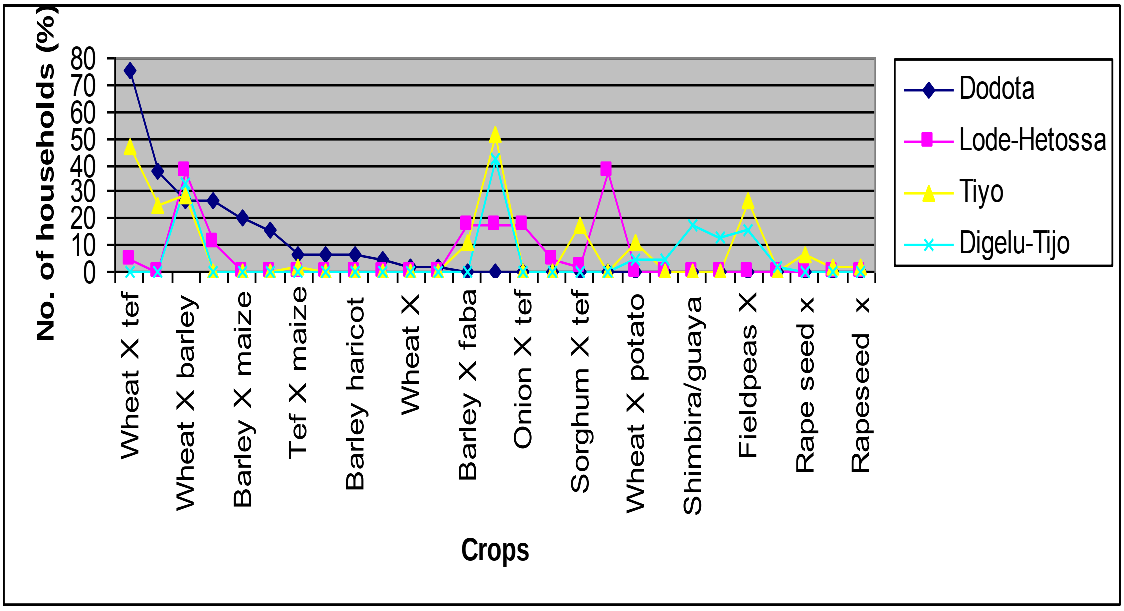

Fig. 23. Crops used in rotation in different weredas.

5.4.3 *Use of organic and inorganic fertilizers*

The results revealed that the farmers were using different agricultural inputs to improve land productivity which included inorganic fertilizer (DAP and Urea), compost and manure either separately or in mixture. Twenty four percent (n = 44) of the total households (n = 180) used only inorganic fertilizers for crop production. The others 21% (n = 39) of the households used compost and inorganic fertilizers, and 21% (n = 38) used manure, compost and inorganic fertilizers. Only 2.2% of the households were producing agricultural crops without any fertilizer.

The use of agricultural inputs varied among the wealth groups. Forty three percent (n = 26) of the poor, 21% (n = 13) of the medium and 8.5% (n = 5) of the rich wealth groups used inorganic fertilizers. On the other hand, 36% (n = 21) of the rich, 18% (n = 11) and 10%

(n = 6) of the poor of the wealth groups used a combination of compost, manure and inorganic fertilizer. The remaining households were using either compost or manure with inorganic fertilizer. Regarding availability of the inorganic fertilizer, 63% (n = 114) said that the supply was not adequate and 10% (n = 18) also said even if available, it was delivered very late to the area. There were significant ($P < 0.05$) differences in using different agricultural inputs for land productivity improvement among the wealth groups.

5.4.4. Use of improved seeds

Seventy nine percent (n = 140) of the households used improved seeds. The results showed that 86 (n = 51) of the rich, 82 (n = 50) of the medium and 65% (n = 39) of the poor used improved seeds. There were significant differences ($P < 0.05$) in using improved seeds among the wealth groups. These households used improved seeds because of the high productivity of these varieties. But, 41% of the households said that improved varieties were expensive and 62% of them said that these varieties were not regularly available.

5.4.5. Use of traditional crop varieties

The results also showed that 58% (n = 104) of the total households used traditional varieties. Distribution of this result among the wealth groups showed that 61% (n = 36) of the rich, 49% (n = 30) of the medium and 63% (n = 38) of the poor wealth groups used traditional varieties that showed a significant ($P < 0.05$) variation.

5.4.6. Diversity of tree and shrub species used in agroforestry

Trees and shrubs were recorded on farm, homegardens and pasturelands. The study showed that tree and shrub species diversity varied significantly ($P < 0.05$) among weredasand households. There were households who had well-established homegardens with annual and perennial species of more than 50 agricultural crops and tree and shrub species (Fig. 24).

Fig. 24. Well-developed home gardens: Photo from Dodota Wereda top; Lode-Hetossa Wereda, Bottom

The average number of tree and shrub species in homegardens ranged from 2 to 6 whereas the least was recorded in homegardens of the poor households. The rich and medium wealth group households had more diversified homegardens than the poor ones (Fig. 25). The diversity of homegardens differed significantly ($P < 0.05$) among the wealth groups of the households.

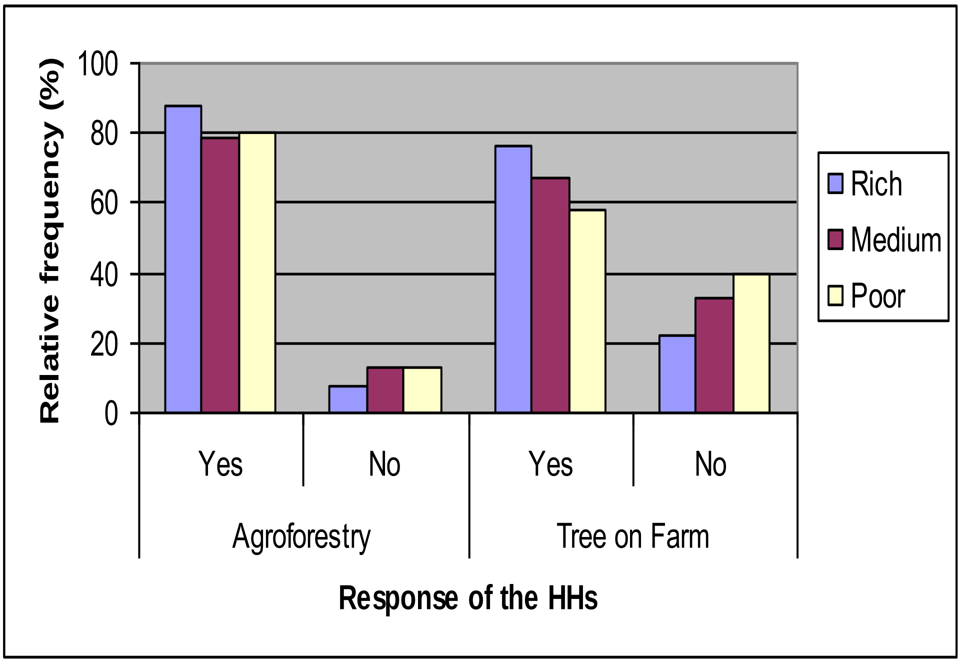

Fig. 25. Households practicing agroforetry and leaving trees and shrubs on farm

6. DISCUSSION

6.1. *Socio-economic Characteristics*

6.1.1. Social characteristics of the housholds

The differences between differenent wealth groups were mainly reflected in socioeconomic factors, which included age, educational background, family size, landholdings and number of animals. The sampled households had different educational background, which ranged from illiterate to secondary school education. The majority of the poor households were found in the age category of 26-35 years. The poor households also constituted the highest number in the category of illiterate and those who can read and write. This implies that education and long term experiences can contribute to livelihood improvement of the local people. The study by Habtemariam Abate (2004) showed that the younger farmers were faster adopters of maize technologies. The importance of education in determining the wealth status of farmers was demonstrated by results from this study and that of Habitemariam Abate (2004). This finding suggests that policies and strategies, which promote rural education and extension programs would be instrumental to improve agricultural productivity and livelihoods of the farmers.

Family size, age structure and availability of extra labor for agricultural production influence the productivity of the agricultural systems. An analysis of households in income shares indicates the extent to which farmers depend on subsistence crops, mainly produced by household members. The results revealed that agricultural production of the households is affected by different socioeconomic characteristics of the households. For instance, diversification of income has a significant effect on the livelihood of the households. Farmers can obtain synergies from the use of technologies, such as diversification, low agricultural inputs and natural nutrient recycling options that they can choose based on their own preferences and their own ability to use specific technologies (Altieri, 1999; Aune and Bationo, 2008).

6.1.2. Landholding and land use patterns of the households

6.1.2.1. Land size of the households

An average of 2.7 hectares of landholding was recorded per household (hh) for the study sites. In all study weredas, the poor wealth group had the lowest average landholding (1.8 ha/hh) while the rich group has the highest average landholding (3.5 ha./hh). This implies that landholding of the households has significant effect on their wealth development. Girma Mengistu (2005) reported that Ethiopia‘s average landholding of the households was about 1.06 ha/hh, and 1.29 ha/hh for Oromia. The higher average landholding of the study area compared to the national and regional figures attributed to the higher average land size per households of Dodota (low altitude) and Digelu-Tijo (high altitude) Weredas. These two weredas are frequently affected by drought and waterlogging, which influence the inhabitants‘ density. Getachew Kassaye (2004) also reported on land size in Southern Nations and Nationalities and People‘s Regional State in which the farm size ranged from 1.75 to 2.26 ha/hh in mid altitude and lowlands. According to the same report, mid altitude zones had small farm size than the low altitude ones. In light of these facts, mean landholding in the present study area could be considered to be around the mean for the country. However, there were big differences in the size of landholding among households ranging from 0.5 to 8 ha. The finding has also shown that 42% of the households had landholding less than 2.0 ha. There were significant differences in landholdings among the wealth groups, which is in agreement with the findings by Zebene Asfaw (2003). Farm size or landholding is one of the farm characteristics that indicate the wealth status of the farmer (Getachew Kassaye, 2004).

The size of the landholding has an effect on the agricultural production. The majority of the rich farmers get additional agricultural land by leasing in from the poor or aged households. The rich and medium wealth group households lease-in agricultural lands while the poor lease-out their land to the others through crop sharing arrangement or on rental basis.

Most of the poor households in the study areas used agricultural lands for annual crops. This coud be attributed to small land size of the households and leasing-out to other users. According to this study, the land size, including use of low-agricultural inputs, diversification of crops and homegardens and number of livestock, had contributed to the formation of different wealth groups among the farming communities and in the diversification of livelihoods of the households. The land size has also a significant impact on the size of livestock owned by the households. The majority of the poor households did not own livestock, due to lack of grazing lands for their animals, lack of purchasing power to restock when their animals died.

6.1.2.2. Land use patterns

The majority of households (77%) used their landholdings for the production of annual crops. Only 20% of the households had allocated land for perennial crops, trees and shrubs. Most of these households allocated less than 0.5 ha of their land for perennial crops. It was observed that homegarden diversity is associated with the wealth status of the households. Most households of the rich and the medium wealth groups had well-developed homegardens, which had different fruits and other perennial crops. The discussions made with the key informants showed that diversified homegardens have contributed to increased household income and livelihood improvement.

Most of the study sites have been deforested for agricultural land expansion to feed the increasing population. The lowlands have been suffering over the last four decades due to soil erosion and lack of enough moisture for agricultural production or erratic rainfall. The grazing lands have been degraded leading to decline in livestock population over time.

On the highlands, there were places where water logging was a limiting factor for agricultural production, particularly, on the flat plains of Digelu-Tijo Wereda and some pocket areas of Tiyo Wereda of which these areas used to be grazing lands in the past.

With the increasing of population and needs for more agricultural production, these lands have been gradually converted to areas for agricultural crop production and planting of *Eucalyptus globulus* and some other tree and shrub species. However, the crop production in these areas had not been satisfactory. Diversifiation of sources of income for these areas is very crucial to improve the livelihood of the farmers. Several income generation strategies contribute to increased value of crop production, without having significant impacts on land degradation, including mix of annual and perennial crop production, livestock and non-farm income strategies (Pender *et al*., 2004).

It was observed that farmers with well-developed homegardens obtained substantial amount of income (ranging from ca. Birr 5,000 to 7,000/year) from different crop products and livestock. Homegrdens also ensure continuous flow of income throughout the year. The micro-climate of the homestead is highly improved. These observations are in line with the reports of Brussaard *et al*. (2007) and Jackson *et al*. (2007) on developed polycultured homegarden using water harvesting in all climatic zones. Farmers with established homegardens had fruit trees, vegetables, fodder trees, grasses and annual crops. They produce the whole year for home consumption and generation of income.

6.1.3. Livestock resources

The results showed that livestock is very important for the livelihoods of the local community through provision of animal products (meat, milk, hide, egg), animal draught power, fertilizing agricultural land and income generation. Due to feed problems and lack of restocking capacity, the majority of the poor and some of the rich and medium wealth groups lack different livestock types. Number of livestock and the size of landholding varried significantly among the wealth groups and weredas. These situations have direct impact on the production capacity and livelihood situation of the households. There is also variation among the weredas. The rich households in Tiyo Wereda have the highest number (7.3) of livestock than other weredas.

Both livestock size and landholdings play a significant role in diversification of agriculture, tree and shrub species and ensure food self sufficiency. This result is in line with the reports of Tschakert (2007), Zingore *et al*. (2007) and Hailu Beyene (2008) which showed that richer households have larger overall landholdings (almost three times as much), more valuable agricultural equipment, and higher annual income and expenditure.

Livestock is a very important component in the Ethiopian agriculture. The highland farmers are practicing mixed farming by integrating livestock with crop production, for their livelihood, whereas the pastoralists of the lowlands subsist mainly on livestock and livestock products (Girma Mengistu, 2005). Generally, livestock is considered as an asset that could be used either in the production process or be exchanged for cash (particularly small ruminants) for the purchase of inputs (fertilizer, herbicide and insecticide) whenever the need arises. Draught animal power, in addition to other economic benefits, provides an important source of energy in the mixed farming systems of the world and helps to reduce dependence on nonrenewable fuel sources.

Mixed farming is probably the most benign agricultural production system from an environmental conservation perspective because it is, at least partially, a closed system, because it provides many opportunities for recycling and organic farming. Livestock play a significant role in maintaining soil fertility. In partially closed mixed farming systems, livestock can replenish a substantial share of soil nutrient, and, therefore, reduce the need for inorganic fertilizer, with corresponding savings for farmers in terms of cash outlay, for the country in foreign exchange, and for the world in non-renewable resources. This was confirmed by the research conducted by Zingore *et al*. (2007) in Zimbabwe of which both amounts of N and P in organic resources used on the farms were strikingly related to farm resource groups. Animals recycle the nutrient content of plants, transforming them into manure. The need for animal feed also broadens the crop base to include plant species useful for conserving soil and water. Legumes are often planted to provide quality forage but also serve to improve nitrogen content of soils (Altieri, 1999).

Livestock has a significant contribution in income generation and to fill the gaps in food defecit times. The results revealed that the rich and the medium wealth groups depend mainly on livestock to fill gaps in crop production for household consumption. Cattle are the most reperesnted species in all three traditional zones (KOLLA, WEYNA-DEGA and DEGA). Similar result was found by Ceech *et al*. (2010), where the cattle contributed to the livestock population by 30, 60 and 72% for the pastoral, agropastoral and mixed farming systems, respectively in eastern Africa. Livestock systems in developing countries are extremely dynamic due to increasing populations and demand for livestock products, and this is projected to continue well in the future (Thornton *et al.*, 2009). Mixed farming systems provide farmers with an opportunity to diversify risk from single crop production, use labor more efficiently, have a source of cash for purchasing farm inputs and add value to crops or crop by-products. Combining crops and livestock also has the potential to maintain ecosystem function and health and help prevent agricultural systems from becoming too brittle, or over connected, by promoting greater biodiversity, and, therefore, increased capability to absorb shocks to the natural resource base. Modern drivers of change are already having substantial impacts on biodiversity. According to Thornton *et al.* (2009), nearly 4000 breeds of ass, water buffalo, cattle, goat, horse, pig and sheep were recorded in the 20th century, and some 16% had become extinct by 2000, and 12% of what was left was threatened. Much of this genetic erosion is attributed to global production practices and the increasing marginalization of traditional production systems and associated local breeds.

On the other side, livestock and livestock systems are substantial users of natural resources (as a feed) and globally they contribute significantly to global warming through emission of methane, while at the same time they make contributions of critical importance to the livelihoods of at least a billion poor people in rural households, almost all of whom are in developing countries (Thornton *et al.*, 2009). Therefore, improved management technologies are required to deal with multiple and competing pressures on tropical and subtropical livestock systems in the future, to produce food, to feed livestock, and to produce energy crops.

6.2. Composition and Production of Agricultural Crops

6.2.1. Diversity, eveness and distribution

The results showed that individual households grow different agricultural crops, which have different uses. A total of eight functional groups of 44 species were recorded in the study sites. This finding is in agreement with the result from North Shewa and South Welo by Mulatu Geleta *et al.* (2002), which showed that a number of oil crops were cultivated with cereal crops. The same report revealed that the farmers used multiple cropping systems, which stabilize production, especially under adverse environmental conditions. Traditional crop diversity is very important in the provision of yield stability, resistance to biotic and abiotic stresses, has a good resilience and is adapted to low inputs in agriculture. According to Jackson *et al*. (2007), in Nepal, traditional varieties of rice (*Oryza sativa* L.) continue to be important because of their capability to survive in mid—hill areas while traditional varieties of barley in Syria were preferred for greater yield stability, adaptation and resiliences to stresses.

Diversity of crops has impact on the productivity of the households. The results showed that those farmers who mixed different annual and perennial crops have better annual income. Farmers' use of polyculture and/or agroforestry strategy minimizes risk by planting several species and varieties of crops, stabilizes yields over the long-term, promote diet diversity and maximize returns under low levels of technology and limited resources (Altieri, 1999). Many studies conducted in different tropical countries (e.g.

Altieri, 1999; Brussaard *et al*. 2007; Jackson *et al*., 2007) have shown that farmers traditionally use mix of crops to avoid risks and to use for different purposes. Benin *et al*. (2004) reported that, in the highlands of Amhara and Tigray regions, 24% of the farmers cultivated one cereal only, while 40, 27, 8 and 1% cultivated two, three, four and five cereals, respectively. But, in the present study, all the respondents were growing two or more crop species. Another report by Altieri (1999) showed that much of the production of staple crops in the Latin American tropics occurs in polycultures of which more than 40% of the cassava, 60% of the maize, and 80% of the bean in that region are grown in mixtures with other crops.

The farmers are using agricultural crops for consumption and income generation. Wheat, barley and TEF are used for family consumption and income generation, while onion, linseed and other oil crops are produced for income generation. Most of the farmers (92%) practice crop rotation by using cereal crops with leguminous crops to improve land productivity. Fabaceae constituted the highest percentage (20%), followed by Poaceae (14%), of the number of crop species grown by the households. Altieri (1999) reported that in Cuba, alternative models of integrated farming systems (i.e. tree integration, planned crop rotation, polycultures and green manures) to varying degrees, which, with time, have led to enhancement of production and biodiversity, and improvement in soil quality, especially organic matter content. Agrobiodiversity is most likely to enhance ecosystem functioning when a unique or complementary effect is added to an ecosystem using cover crops or intercropping, supporting more parasitoids or insect enemies with specific roles in controlling pests or including a plant functional group, such as a legume, that increases nitrogen inputs and cycling (Jackson *et al*., 2007).

Agroecological farming systems approach have greatly contributed to the design of more sustainable and productive agroecosystems. The same study by Jackson *et al*., (2007) revealed that biological nitrogen fixation by soil biota in agricultural ecosystems was estimated at ca. 140 to 170 millions of N and valued at about US$ 90 billion $year^{-1}$. Many studies in different countries have shown that diversification of agroecosystem increases organic content of soil and improve agricultural productivity (Altieri, 2002, Bationo *et al*., 2007; Nourbakhsh, 2007) through increase in biological activities in the soil and natural recycling of nutrients. Increase in diversity of the legume component in the cropping systems will produce higher quality fodder for the livestock and also increases biomass at farm level.

6.2.2. Similarity of sites in composition of crop species

Geographical location has clear impact on the similarity of crop species among the study kebeles. Kebeles in the same wereda, particularly, those found in Dodota and Digelu-Tijo had the highest similarity index. On the other hand, altitude may be the main factor for the differences among the kebeles, because Shaldo-Jigessa and Burka-Chilalo kebeles, which are located in different weredas but found at the foot of Chilalo-Galema Mountain range have high similarity index (0.67) in composition of agricultural crops.

The least similarity index (0.30) was recorded among the kebeles of Dodota Wereda and Burka Chilalo Kebele of Tiyo Wereda. Most of the kebeles within the same wereda had similar crop species. In most cases, the dissimilarity increased with the distance of one wereda from the other. The differences were attributed to elevation differences where Burka Chilalo is located at the foot of Mt. Chilalo, which is one of the high altitude kebeles from the study sites (2572 m. a.s.l), while kebeles of Dodota Wereda occupy the lowest altitudinal range (ca.1441-1759 m).

There were no distinct differences in composition of crop species among different farms along the gradients. Most of the crop species grow along the altitudinal gradients overlapping with other agricultural crops requiring different niches. Wheat and barley grow from lowland (KOLLA) to highland (DEGA) of the Chilalo Mt. Soybeans and haricot beans are limited to KOLLA areas while faba bean, lentil, and rape seed are restricted to highlands.

6.2.3. Agricultural crops production and expenditure

6.2.3.1. Agricultural crop production

About 766 ha of land have been used for BELG (the short rainy season, which starts in March) and MEHER (long rainy season that starts in June) rainy seasons of the agricultural system of the area. The highest percentage (72%) was used for wheat production. The other main crops included barley, TEF, faba beans, maize, haricot bean, linseed, onion and field pea, which have covered 31, 21, 8, 6, 5, 5, 3 and 3 percent of the cultivated land, respectively. The production analysis has revealed that the total production of agricultural crops for the studied year was 8,310 quintals from an average cultivated land of 2.5 ha per household (a total of 18 quintals per household). The total value of this production was estimated at Birr 3.4 million (Birr 7440 per household).

The yield data was obtained for sixteen annual crop species of which wheat has the highest share of land area, total production and income generation. About 49% of the income from the agricultural crop production of the households comes from wheat production. The production per hectare was estimated at 1.1 t/ha which was equivalent to the national average reported by Alemayehu Assefa (2003).

The diversity of agricultural crop species and quantity produced varied among the households and weredas. These may be attributed to the availability of water, edaphic factor and resources endowment. The poor households lack adequate draught animal, landholdings and livestock, which can be sources for manuring their agricultural lands. Discussions conducted with key informants showed that shortage of rainfall in Dodota Wereda and water logging in Digelu-Tijo Wereda had significant negative impacts on agricultural crop production.

Due to low land productivity and high average costs of production of agricultural crops (Birr 7,565 ha^{-1}), significant number of households could not produce enough food for their families. The study showed that the medium wealth group and the poor households produced Birr - 551 and Birr - 2,247 ha^{-1} incomes from production of agricultural crops, respectively, while only the rich households produced Birr 343 ha^{-1}. The majority of the poor households (67%) were dependent on external supports or some of the family members migrate for search of employment to feed their families. These results showed that the farmers are dependent on different sources for their survival, and this has an effect on saving of the households for the improvement of their livelihoods.

6.2.3.2. Cost of agricultural crops production

The cost of production varied fom wereda to wereda, based on the distance from the market, land productivity, crop species and availability of agricultural land. Lode-Hetossa Wereda, where average landholding was the lowest (1.9 ha) compared to other weredas, had the highest land lease-in which raised the cost of production in this Wereda. In addition, this Wereda has been known for its highest production of cash crops, particularly onion. Labor cost and competition for agricultural land has exacerbated the expenditure for agricultural production.

Availability of labor, land productivity and proximity to the urban areas affect the cost of producton. Digelu-Tijo where water logging is the main limiting factor for agricultural production, had lowest land lease-in cost and low demand for labor, so that, agricultural crop production cost was the lowest compared with other weredas. The cost for agricultural inputs has not varied from wereda to wereda due to the proximity of the source of agricultural inputs to the main road of all the study weredas. Land demand in Dodota Wereda was also low due to erratic rainfall and unreliable agricultural production systems of the Wereda.

6.2.3.3 Household income from different activities

Our results showed that all of the respondents have been earning income from different sources. The amount of income varied among the wealth groups. The main sources of income were livestock and off- farming activities. Those households who use polyculture have produced more agricultural yields than the others with few crops. Diversification of agricultural crops can benefit the households to diversify income sources and minimize costs of production, which is in line with the report of Farooquee *et al*. (2004) that showed the importance of income diversification for the high altitude society in Kumaun Himalaya, India. On the other hand, farmers use a range of approaches to deal with risks, such as choice of crop varieties, use of fertilizer, food crops or cash crops, planting density, water harvesting, fodder storage, sale of livestock, migration and off-farm income (Aune & Bationo, 2008).

6.2.3.4. Costs and benefits of agricultural production

The benefit of the households from the agricultural production depends on total production costs, climatic situation, land productivity and prices of the products of the agricultural crops. Important differences were identified among smallholder individuals regarding assets, knowledge and agricultural practices, which affect the income of the households (Tschakert, 2007), which also influence the houshods' ability to adopt land and soil fertility management practices.

Our results revealed that the total net income of the households from agricultural crop production varied from wereda to wereda. The lowest income for Lode-Hetossa was attributed to the highest land lease-in cost. The net income of Dodota and Lode-Hetossa was negative which is in agreement with the report of Zingore *et al*. (2009) which showed that the poor farmer had a negative cash balance for the cropping system. Monthly, cash balances for the poor farmer were positive only for five months. The rich households had the highest expenditure for different purposes. Both the poor and the rich spent the highest cost for land leasing followed by the purchase of improved seeds.

A study made by Taschakert (2007) in West-Central part of Senegal has also shown that costs of agricultural crop production for resource-poor farmers were considerably higher than for intermediate and richer farmers, due to the fact that the former often lack the necessary assets (land, labor and animals) to switch from current to alternative practices. The same study has also shown that the wealthy farmers generated a small amount of cash from off-farm activities but spent substantial quantities of cash on children‘s education, healthcare and the purchase of food.

6.2.3.5. Trends of agricultural production

The data for five years period did not show a significant change in agricultural production of the study area, eventhough the majority of the households (66%) said that crop production over the last five years has been increasing. The increment did not substantiate a significant change ($P < 0.05$) on the agricultural production. One third of the respondents further said that production decreased over the last five years. Based on the quantitative information, five years production of the households did not show continued increasing trend. On the other hand, Holden and Bekele Shiferaw (2004) reported in the Andit Tid, ca. 60 km north of Debre Berhan decline in yields of barley over a 5-year period with and without conservation technologies and without and with a fairly high level of fertilizer application.

6.2 Diversity, Richness and Distribution of Tree and Shrub Species along the Study Sites

6.3.1. Diversity and richness of tree and shrub species

The results showed that there is still a high diversity of tree and shrub species remaining in the area. Many tree and shrub species have been recorded in farmlands, homegardens and pasturelands. In all kebeles and weredas the rich households have more tree and shrub species than the poor households, which is in agreement with the study made in the Sidama Zone by Zebene Asfaw (2003).

Biodiversity in agricultural landscapes can contribute significantly to agricultural productivity, food security and financial return. Diverse tree and shrub species can enhance livelihood security and generate income as well as supporting adaptability and resilience to changing environmental and economic conditions. The original diversity (number and density) of tree and shrub species has been modified by the farmers over the last 6 to 7 decades for agricultural expansion, through charcoal making and over grazing.

Acacia has the highest number of species in the lowlands whereas the other genera were represented by a few species along the study areas. The trees and shrubs varied in density and composition along the environmental gradients. Many acacia trees are being used for home consumption, income generation and agricultural land productivity in the lowlands. The middle and highlands were covered with different tree and shrub species, which have different purposes. *Eucalyptus* species are used for fuelwood, construction and income generation whereas sesbania and treelucern are used for animal fodder. Different temperate and tropical fruit trees and shrubs are grown for consumption and income generation.

Variations in species diversity and structure are probably a result of selective pressure through human exploitation and differences in elevation and soil types. The species diversity of the study area is comparable to what has been reported for other study areas; for instance 120 tree and shrub species have been recorded in homegarden agroforestry systems of southern Ethiopia (Tesfaye Abebe, 2005). According to Garrity (2004) as much as 90% of the biodiversity resources in the tropics are located in human-dominated or working landscapes.

The lowlands of the study sites used to be covered with dense *Acacia* spp. before 5-6 decades. But, now, most of the lands are devoid of vegetation and soil erosion by wind and water has been very severe. The farmers put these woodlands under annual crops. These crops could not produce adequate products over time due to degradation of agricultural land and change in climate and erratic rainfall. Changes in land cover (i.e. the biophysical attributes of the earth‘s surface (Belcher *et al*., 2004; Cecchi *et al*., 2010) readily signal human interventions and can affect the ability of biological systems to sustain human needs, including the ability to support agricultural systems. This has an effect on the availability of nutrient and water for the plants. A review made by Brussaard *et al*. (2007) on soil biodiversity for agricultural sustainability showed that the organically managed soil was more stable than the intensively managed soil. Increasing nutrient efficiency means lower demands for the often scarecely available or affordable artificial fertilizers.

Farmers in the highlands of Central Ethiopia rake the excess foliage litter under *Hagenia abyssinica*, *Dombeya torrida* and *Senecio gigas* trees and use them as sources of organic fertilizer for the nearby crop fields (Kindu Mekonnen, 2007). The same study revealed that the content of P, K, Ca and Mg in the soil beneath *H. abyssinica, S. gigas* and *Cytisus palmensis* were relatively high as compared to the other species (*Buddleja polystachya* and *D. torrida*). Enrichment of these nutrients beneath the three species could be associated to the rooting system and efficient nutrient cycling power of the trees. Deep-rooted trees and shrubs often act as nutrient pumps taking nutrients from deep subsoil horizons into their root systems, translocating it to their leaves and recycling it back to the surface of the soil via leaf fall and leaching.

The diversity index revealed that many tree and shrub species were recorded in Tiyo and Dodota weredas. This may be attributed to high natural regeneration of *Acacia* species in Dodota and better stock of the remnant indigenous species at Tiyo Wereda. In addition, many households had tree and shrub species in their homegardens in Tiyo Wereda. Also, the evenness index was very high (0.7) for all weredas except Digelu-Tijo Wereda (0.6) where the grasslands have been revegetated through planting of exotic species, mainly *Eucalyptus globulus*. Evenness index is the lowest for this Wereda which can be attributed to uneven distribution of tree planting by the studied households. Some of the farmers in the study areas had many tree and shrub species in their homegardens while the others do not have any. Given that agricultural landscapes are prone to disturbance, succession can be more rapid when some indigenous plants remain, seed banks exist and neighboring intact biodiversity-rich vegetation still serves as a source of dispersing organisms (Jackson *et al*., 2007). Thus, avoiding fragmentation of native vegetation is important for a range of supporting and regulating services, but also cultural and provisioning services, such as extraction of non-timber forest products (NTFP) and the germplasm of NTFP-producing species for domestication.

6.3.2. Distribution of tree and shrub species along the study weredas

The highest variation in the distribution of tree and shrub species was recorded between Dodota and Digelu-Tijo weredas. The other weredas have many common species. *Eucalyptus globulus* was found in all the three weredas with the highest proportion. My result showed that 60, 91and 100% of the households of Lode-Hetossa, Tiyo and Digelu-Tijo weredas had *Eucalyptus globulus*, respectively. All the households in Digelu-Tijo have *Eucalyptus globulus* in their homegarden or farmlands. *Eucalyptus globulus* has the highest relative values (Annex 3) for substantial number of the use categories, which can be attributed to fast growth rate, coppicing, multiple use, wide range of adaptability to different ecological niches and easy management requirements.

The results of showed that differences in altitudes and distances of weredas from each other have effects on similarities in composition of tree and shrub species along the weredas. The lowlands are mainly occupied by *Acacia* species while the highlands of Digelu-Tijo have limited number of species dominated by *Eucalyptus globulus*. There is a broad overlap and scattered tree and shrub species along the environmental gradients, rather than the formation of distinct, clearly specialized zones. Berhanu Mengesha (1997) reported that variation with vegetation formation tends to be continuous along the topography without sharp boundaries due to geology, which manifest itself in various ways relating both to topography, chemical and physical properties of the soil.

The vegetation distribution at a given altitude is determined by the physical environment such as temperature or biological environment and competition. Temperature, soil, moisture availability and human disturbance are the three most important environmental factors affecting floristic composition (Berhanu Mengesha, 1997). The upper altitudinal limits of species are determined mainly by temperature and related factors, whereas downward ranges are generally influenced by competition. Species distribution is usually related to the disturbance history, or edaphic factors such as physiography, soil depth, nutrient content and texture (Denslow, 1987). Each species is distributed according to its genetic, physiological and life-cycle characteristics to its way of relating to both physical environment and interactions with other species. Most of the study sites in Digelu-Tijo and parts of Tiyo Weredas were mainly water logged so that only few species such as *Eucalyptus globulus, Sesbania sesban* and *Cupressus lusitanica* were recorded in these sites. The well drained areas of Chilalo Mt. ranges and lowland areas of Dodota Wereda had a high number of species. The main determinant factors observed in all places, regarding tree and shrub species diversity, were extensive agricultural expansion, edaphic factors and overgrazing.

6.3.3. Ethnobotanical knowledge of the local communities

6.3.3.1. Use-categories of the tree and shrub species

It was found that the different species at different elevations had specific importance to the local communities. Some of the species had many uses while the others were used for certain purposes. Considering all use categories, species such as *Eucalyptus globulus, Hagenia abyssinica, Acacia tortilis, Cordia africana, Acacia abyssinica, Juniperus procera, Olea europaea, Podocarpus falcatus* and *Croton macrostachyus* appeared to be the most exploited and, therefore, are the most useful to the local people. *Eucalyptus globulus* is planted in all the middle and highland areas of the study sites and covers most of the use categories (82%) compared to other species. The majority of the tree and shrub species were used for more than one use categories. The farmers use many indigenous and exotic tree and shrub species for multiple purposes, including food, feed, agricultural productivity improvement and other forest goods. The knowledge of tree and shrub species would help to promote the use of these species and their sustainable management. These species can be used as a source of income and healing from different diseases. Cocks and Dold (2006) reported that 60 plant species were traded in urban markets in the Eastern Cape of South Africa for income generation.

A study conducted in the highlands of Ethiopia by Mekoya Abebe *et al.* (2008) showed that the farmers were using both indigenous and exotic multipurpose tree species for production of fodder. From the participatory rural appraisal of this study, it became clear that tree and shrub species on farmlands in the study sites are important to the rural households. Garrity (2004) and Kalaba *et al*. (2009) reported about the importance of trees and shrubs on agricultural lands. About 90% of the wood used in Bangladesh is produced on agricultural land (Garrity, 2004).

The household heads, key informants and focus group discussants stated that natural and anthropogenic factors were responsible for changes in land use. Deforestation has increased the vulnerability of most rural households, due to shortage of forest goods and services, which directly affect the livelihoods. The key informants, particularly, in the lowland areas underlined that the change in climate and frequent drought have been the result of unabated deforestation of the acacia woodlands. They also expressed that there has been some improvements in recent years after the regeneration improvement of *Acacia* and some other species in the areas.

Understanding and valuing traditional and current farmers' ecological knowledge and land use practices are important aspects of promoting conservation of tree and shrub species on farmland for multiple purposes. Based on this study, it is clear that the use of trees and shrubs for subsistence is of great importance to people in the Arsi highland. The primary use categories for tree and shrub species are environmental protection (conservation, improve productivity, shade and windbreak), fuelwood, construction and food and feed for human and animals. This implies that loss of tree and shrub species has a negative impact on the livelihoods of the local communities and the environment.

Management of the environment and natural resources, like soil, water, air, flora and fauna, has become an issue of unprecedented global concern. Yet, the objectives of natural resource management, including conservation, quality control and equitable distribution among people, often create more problems than solutions. There is also a need to study and act on these concerns across the various cultural, social, economic, and even political boundaries; otherwise knowledge and practice would become two worlds apart. Combining this traditional and modern knowledge can help the rural communities to manage the diversity of their farmlands to maintain or even improve their productivity. This knowledge is also useful to agronomists, foresters, conservationists and extension workers to assist communities in the management of their resources. Ethnobotanical knowledge should also be used to guide and prioritize future agricultural and forest research and education. Also, sustainable forest management has to be linked to improvement in agricultural productivity and to the opportunities offered by a wider economy.

6.3.3.2. Relative importance and use-values of tree and shrub species

Forest resources provide a substantial contribution to the livelihoods of the many rural households. Tree and shrub species on farmlands are used for provision of fuelwood, construction materials, fodder, food, medicine and other environmental protection services. Due to deforestation of the acacia woodlands and moist highforests of the Zone, most of the tree and shrub species are managed on the farmlands and in homegardens. According to the key informants and the discussions made with focus groups, the natural forests have been cleared and converted to agricultural lands over the last six decades. Remnant tree and shrub species have been left only along the river banks, on farm boundaries and in homesteads. According to the key informants, the most important medicinal plant (such as MANDERA, in Afan Oromo, Oromo language), has been lost from the area.

Distributions of most of the tree and shrub species depend on altitude. *Acacia* spp. are dominant in the lowlands while the commercially important tree species, including *Podocarpus falcatus, Juniperus procera* and *Eucalyptus globulus* are limited to the middle altitude and the highlands. Saxena *et al*. (2005) reported that tree density in the Himalayan mountain system is in the range of 182 to 419 trees per ha and species richness in the range of 8 to 90 species which is much higher (0.2 tree/ha) than those found during this study. Crop and tree diversity (both within and between species variation) are important to farmers for risk avoidance, income diversification, and adaptation to changing environmental conditions. Tree and shrub species are important natural resources for the diversity of soil organisms, which contribute to a wide range of essential services to the sustainable functioning of agroecosystems through nutrient cycling, regulation of the dynamics of soil carbon sequestration, effects on soil physical structure and water regimes and influence on plant life, nitrogen fixation and the interactions in the soil of pests, predators and other organisms.

The biodiversity maintained by farmers is not only of benefit to them but also to society as a whole, because of its role in maintaining ecosystem services such as erosion or disease control. A fundamental challenge for the country over the next 10 to 25 years is to increase food production and improve the livelihood of small-scale farmers. This has to be done in an ecologically sustainable manner that does not increase vulnerability and land degradation but still improves profit margins and livelihoods of poor farmers and small-scale producers. The number of users of traditional medicine (ca. 14% of the respondents) was low compared with modern health centres. This may be attributed to the loss of medicinal plants due to clearance of vegetation for agricultural land and other land uses. _

6.4. Alternative Technologies for Sustainable Agricultural Production and Ecosystem Conservation

The development of self-sufficient, diversified and economically viable small-scale agroecosystems comes from innovative-designs of cropping and /or livestock systems managed with technologies adapted to the local environment within the farmers‘ resources. This approach considers resource conservation, environmental quality, public health and equitable socioeconomic development in making decisions on crop species, rotations, fertilizing, pest control and harvesting. These components are organized in a strategy that highlights the conservation and management of local agricultural resources following a development methodology that emphasizes participation, traditional knowledge and adaption to local conditions (Altieri, 1995). Different biophysical, socioeconomic and cultural factors influence sustainable productivity of agricultural systems and ecosystem conservation. These factors have shown significant differences among the wealth groups. Resource endowment of the households and diversification of income sources contribute to asset building and livelihood of the households. This finding showed the importance of supporting the farming communities to minimize their dependency on few agricultural and annual crop species. However, the current situation shows that the farmers are more dependent on agricultural crop and livestock incomes, which are in agreement with Zingore *et al*. (2007).

6.4.1. Diversification of agricultural crop species

Biophysical factors, such as, altitude and slope of the farms, have affected diversity of crop species. In the lower altitude of the study sites, the share of lowland crops is higher due to high temperature and capacity of these species to adapt to higher temperature. The study has shown that farmers with diversified cropping system have better income than those depending on few agricultural crops. This was reflected in Tiyo Wereda where the numbers of crops and plant species were the highest in number than other sites. The report of Altier (1999) has also shown that there were yield advantages, which can range from 20% to 60% higher than under sole cropping with the same level of management in Latin American countries. Most multiple cropping systems developed by smallholders have increased productivity in terms of harvestable products per unit area. These differences can be explained by a combination of factors, which include the reduction of losses due to weeds, insects and diseases and a more efficient use of the available resources of water, light and nutrients. In addition to biophysical and landscape gains, diversity provides other economic gains, such as resilience of crop against biophysical and economic shocks, nutritional and health. The areas with high biodiversity have been shown to have the highest income per household.

Perennial crops also have multiple purposes. In addition to increasing production, they help in covering agricultural land for soil and water conservation and microclimate improvement of the areas. For example, the discussions made with key informants showed that vegetation degradation resulted in accelerated soil erosion, decline of land productivity and change in climate. As a result of these phenomena, increase in temperature has changed the niches of crop varieties. Lowland varieties of maize are being grown on the Chilalo Mt. ranges while varieties which were used in lowlands have failed to tolerate the increased temperature of the areas. Therefore, crop biodiversity is an important asset both for increasing agricultural productivity and minimizing the risk of climate change (Sinafikeh Asrat *et al*. 2009).

Diversification can be temporal or spatial which can benefit the farmers for simultaneous production or at different times to increase production. According to Adamu Molla (2004), a mixture of 75% barley + 25% wheat, 50% barley + 50% wheat, and 25% barley + 75% wheat, respectively, gave relative yield total values of 1.17, 1.41 and 1.20 for grain yield. In other words, mixtures gave grain yield increase of 17, 41 and 20%, respectively. To produce equal yield by a single crop requires 17, 41 and 20% land increase. On the other side, it can improve the niche for mutually benefiting crop species.

6.4.2. Crop rotation

Most of the farmers (92%) in the study sites used crop rotation. The farmers rotate leguminous with non-leguminous species (51% in Tiyo Wereda) or non-leguminous with non-leguminous species (76% in Dodota Wereda) based on their growing requirements. Particulary, in the highlands, the farmers produced twice a year so that there is crop rotation between onion and wheat, potato with wheat or barley. Altieri (1995; Pender *et al*., 2004) reported that crop rotations influence plant production by affecting soil fertility and survival of plant pathogens, physical properties of soils, soil erosion, and soil microbiology and prevalence of nematodes, insects, mites, weeds, earthworms and phytotoxins. Agroecological approaches in Brazil have also shown that the adoption of maize-soybean rotations increased yields, slowed soil erosion and pest and disease problems that affected soybean monocrops (Altier, 1999).

6.4.3. Use of organic and inorganic fertilizers

The majority of the farmers (98%) were using different types of agricultural inputs for agricultural production. The rich and medium wealth group farmers used mix of organic and chemical fertilizers while the majority of the poor used chemical fertilizers for agricultural production. According to a study made in Zimbabwe by Mazvimavi and Twomlow (2009), seed, fertilizer and fencing material shortages in rural retail markets are constraining farmers‘ initiatives to expand sustainable agricultural practices.

Dependency on industrial fertilizer by the poor households was attributed to lack of livestock and lack of use of leguminous crops for land productivity improvement. Poor households use expensive agrochemicals for crop production while their agricultural production was the lowest compared with the other two wealth groups. This shows that technical and financial support is very important for the poor households to use locally available materials like manure, compost and green manures to improve their land productivity rather than depending on expensive industrial agricultural inputs. Production resources include the agricultural out-put of the farm such as crops and livestock. These become capital resources when sold and residues (crops and manure) are nutrient inputs reinvested in the system.

It was also found that agricultural production of the rich houshods has been higher than those poor households who used only inorganic fertilizers. Similar studies made in different countries have shown that efficiency of inorganic fertilizers depends on the mix with organic fertilizers (Tittonell *et al*., 2007; Nourbakhsh, 2007). According to Bationo *et al*. (2007), long-term field experiments in the West African agroecosytems showed that the use of mineral fertilizers without recycling of organic materials resulted in higher yields, but this increase was not sustainable. The same study asserted that the decline in soil organic carbon by 25-50% had resulted disappearance of indigenous organic matter during the first two years of cultivation in Burkina Faso, which also, increased nutrient leaching and lowered the base saturation that aggravated soil acidification. In addition, the report of Xu and Mage (2001) has shown that the level of the organizational health of the agroecosystem had declined by 16.7% in 20 years due to increase in the proportion of crop land area sprayed with toxic chemicals.

The use of microfertilisation with other low-cost technologies such as mulching, seed priming and water harvesting is presented as a key to agricultural intensification in the drylands of West Africa as this technology can increase yields by more than 50% (Aune and Bationo, 2008). A study conducted in Vietnam by Affholder *et al*. (2010) showed that mulch increased grain yields by 45% for maize and 18 to 31% according to years for rainfed rice, as compared to the conventional system.

Zingore *et al*. (2009) identified that the high N balance on the wealthy farm was driven strongly by the use of manure and mineral fertilizers. Maize fertilized with a combination of fertilizer and manure resulted in higher income and less–negative nutrient balances than maize fertilized solely with mineral fertilizer. Altieri (1999) reported that the use of intercropping with legumes and soil and water conservation practices in Honduras had tripled the agricultural yields fom 400 kg ha^{-1} to 1,200-1,600 kg ha^{-1}depending on the farmer. This finding is similar to the study areas where the farmers who are rich and medium use mixed farming systems have improved their agricultural production. The use of legumes does not only increase the yield but it also decreases production costs and avoids environmental contamination by agrochemicals.

6.4.4. Use of improved seed

The majority of the farmers (79%) preferred to use improved varieties because of their high productivity. But the introduction of these varieties forced the farmers to lose their traditional varieties. The availability of these improved varieties has not been on regular basis and farmers have been complaining about the availability of improved seeds. According to Hailu Beyene (2008), research has been undertaken on TEF and wheat variety improvement for more than 30 years in Ethiopia, which had released ten improved TEF varieties and 36 bread wheat varieties from 1974 to 2001. According to the same report, farmers revealed that most of the introduced crop varieties have already disappeared due to loss of their productivity within 2-3 years. Agricultural inputs which are very important to ensure the productivity of these varieties are not available or they are not delivered on time.

6.4.5. Use of traditional crop varieties

The results of the study revealed that traditional crop varieties are still used by some (58%) of the studied households. Most of the poor households (63%) and only 49% of the rich households use traditional crop varieties The study showed that some of the farmers could not find these traditional crop varieties because of their replacement by improved varieties. Sinafikeh Asrat *et al*. (2009) reported that farmers have higher preference of crop varieties for environmental adaptability and stability to productivity, which could be the case for low adoption rate of high yielding varieities. Another report by Farooquee *et al*. (2004) showed that, in the central Himalayan region, over 40 land race crop species selected by farmers are cultivated across the altitude but the area supporting a variety of traditional crops has declined by 72-95%. These crops have mostly been replaced by high yielding varieties and cash crops.

According to Jackson *et al*. (2007), within traditional production systems, different needs exist and farmers and communities opt to maintain a number of traditional varieties because they: i) meet their multiple needs more closely than modern ones such as legumes (e.g. *Phaseolus* spp.) that provide both food and forage; ii) perform better under low levels of external inputs such as pesticides and hebicides; iii) are less sensitive to abiotic stress, e.g. bean landraces (*Phaseolus vulgaris*) for drought resistance in the Mexican Highlands; and iv) are composed of genotype mixture that minimize risk in different types of seasons, e.g. barley (*Hordeum vulgare*) in terminal drought environments in Syria. Gatachew Kassaye (2004) reported that most farmers in mid altitude zone (27.2 to 45.7%) and in the low land zones (47.4 to 57.9%) preferred local maize varieties for food and marketing characterisitics. Generally, farmers in both agroecological zones preferred the improved maize varieties for yield characteristics, whereas the local varieties were preferred for storage and price characteristics.

According to Jackson *et al*. (2007), in Nepal, traditional varieties of rice (*Oryza sativa*) continue to be important in many different agricultural landscapes, even in the lowland areas, where there is a significant intensification, up to 20% of the area may be planted with local varieties. On the other hand, Habtemariam Abate (2004) reported that 51% of the respondents do not use improved seed of maize at all in Shashamane area.

6.4.6. Homegarden diversification and agroforestry promotion

The numbers of tree and shrub species on the farmland have been shrinking from time to time. The acacia woodlands of the lowland of Dodota Wereda and high forest of Tiyo and Lode-Hetossa weredas have been cleared over decades for agricultural land expansion. Monocropping of few cereal crops has taken place in most of the study areas. Traditional varieties and/or land races of agricultural crops have been replaced by modern varieties. These modern varieties need different agrochemicals for land productivity improvement, crop protection and weed suppression. The discussions with the local communities have shown that supplies of agricultural inputs are not adequate and timely.

Promotion of multipurpose tree and shrub species is an alternative to human and naturally induced problems, including soil erosion, the decline of agricultural land productivity, scarcity of animal feed and other goods for households‘ consumption. Agroforestry is an old and widely practiced land use system in which trees are combined spatially and/or temporally with agricultural crops and/or animals which is now becoming the technology of the time that is sustainable. Agroforestry denotes a sustainable land and crop management sytem (Farrell and Altieri, 1995) that strives to increase yields on a continuing basis by combining the production of woody forestry crops (including fruit and other tree crops) with arable or field crops and or animals simultaneously or sequentially on the same unit of land and applying management practices that are compatible with cultural practices of the local population.

The diversifications of tree and shrub species and agricultural crops have significant contribution to the income of the farming communities. The rich farmers used more diversified agricultural crops, trees and shrub in homegarden than the other two wealth groups. Tree and shrub species provide different benefits to the local communities, which includ food, feed and income. They also help to improve land productivity through replenishment of nutrients through litter production. The key informants and FGDs have shown that there are climatic improvements in the lowlands of Dodota, due to exclosure which has contributed to the improvement of natural regeneration of the acacia woodlands. Farmers who practice water harvesting in all the study areas have made a significant improvement on their income. The homegardens of the households have different tree and shrub species, vegetables and agricultural crops.

7. GENERAL CONCLUSIONS AND RECOMMENDATIONS

7.1. Conclusions

The findings of this study revealed that natural and human resources and the use of traditional farming systems combined with contemporary scientific knowledge are very important for sustainable improvement of the livelihoods of the farming communities and ecosystem conservation. The study showed that agricultural land size, family size (availability of labor), diversification of agricultural crops, tree and shrub species and use of combined agricultural inputs have played a siginifcant role in the creation of different wealth groups of the study households. The most important elements are the area of the farm, including its topography, the degree of fragmentation of the holding, the availability of water, average rainfall and vegetation, which may be an important source of food, animal feed, construction materials and medicines for humans. Farm-scale analysis of resource use showed a need to adjust the existing technical recommendations based on agroecological conditions, to account for farm resource endowment (land, fertilizers, manure and labor) and variability in soil fertility within farms, as well as competing resource use options.

The results indicated that there is limited scope to improve productivity and income of smallholder farmers with their existing fertilizer and labor resources (and hence no access to manure) who lack the resources to hire labor. Although, cultivation of crops with little fertilizer or organic nutrient inputs by smallholder farmers is viewed as the main cause of poor crop productivity, the current efforts to increase fertilizer use must also consider other complex factors driving farmers' decisions on crop and livestock management, such as labor output prices. Investment in agricultural development on the poorer farms should focus on attainment of food security using technologies that require less labor, while diversification of the sources of incomes to complement agriculture may offer realistic opportunities to reduce poverty in the long term.

Introduction of improved varieties of agricultural crops has caused loss of landraces or farmers' varieties. Dependence on few improved species resulted in genetic deterioration and loss of very important crop varieties, which used to be tolerant to different environmental stress. Another problem was lack of adequate supply of modern varieties and agricultural inputs, which further exacerbated the problems of the farmers. The external inputs have, however, substituted natural control processes and resources, rendering them more vulnerable. Pesticides have replaced biological, cultural and mechanical methods for controlling pests, weeds and diseases. Chemical fertilizers have substituted for livestock manure, composts and nitrogen-fixing crops. Management decisions come from researchers and extensionists without considering local knowledge and low-input local sources. Thus, modernization of agriculture has induced adverse environmental and social impacts. This situation has called for a new approach to reverse the negative trends of agricultural production and to practice sustainable agricultural production to avoid environmental problems and alleviate poverty through maximum production.

The requirements to develop sustainable agriculture are not only biological or technical, but also social, economic and political, which are needed to create a sustainable society. The final requirement of an ecological agriculture is an evolved and conscious human being whose attitude toward nature is that of coexistence and development, not exploitation and distruction.

Therefore, to ensure the development of sustainable agriculture and natural resources conservation, creation of enabling policy environment generating and disseminating appropriate technologies, targeting disadvantaged groups, improving support services and encouraging community participation, improving physical infrastructure and social services and developing non-farm income-earning opportunities, are the main areas to be considered in macroeconomic policies of the country.

7.2. Recommendations

Sustainable and multifunctional agricultural systems involve integrating the needs of agricultural production with the objectives of environmental protection, including biodiversity conservation and the fulfillments of social, economic and cultural needs of the farming communities. Historical agricultural production systems of the Arsi highlands were assessed and the different efforts made by farmers were evaluated. Deforestation and dependence on monocropping resulted in decline in land productivity, environmental degradation, decline of biodiversity and vulnerability to climate change. Due to escalated cost of agrochemicals and fluctuation of crop prices, most of the farmers are reluctant to use industrial chemicals for improving agricultural productivity. On the other hand, degradation of natural pastures and shortage of grazing land have resulted in the decline of livestock population, which could have enhanced natural recycling of nutrients through adding manure to the soil.

Integrated management of biodiversity and agricultural ecosystems is a holistic process that relies largely on locally available resources, climate, socioeconomic conditions and direct involvement of farmers and national and international stakeholders. In addition, an understanding of how limitations to agricultural production at various levels (social, cultural, economic, political, agronomic, biological, environmental, edaphic and genetic) can be overcome is essential, using local or imported resources, knowledge and capacity to predict possible management options and solutions to the sustainable use of conservation of biodiversity in agroecosystems. Therefore, the following recommendations have been made to improve the productivity of subsistent farmers, sustainable agricultural production and agroecosystem conservation:

- Farmers customarily consider a complex of reasons in challenging production situations that are often not assessed or mimicked by researchers. Diversity indices developed for scientific research are often far removed from farmer decision-making processes. Thus, considering best practices of the traditional knowledge combined with modern approach will improve land productivity, biodiversity and agroecosystems of the landscapes for sustainable agricultural production. The agricultural development of the study area needs to be skillfully, thoughtfully and in a participatory scheme guided to this goal.

- Assessing species diversity and community assemblages for multi-functionality, along with gauging inputs to maximize economic benefits and environmental quality is important for sustainable agriculture. Therefore, diversifying agricultural production and developing moisture retention mechanisms will improve the livelihoods of the local people and the sustainable management of the agroecoystems of the area. This requires interdisciplinary research, an ecosystem approach and often site-specific analyses across different types of gradients. Research and development in the study area must be reoriented to achieve desired goals.

- This study assessed only the existing situation of agricultural systems of the study areas, which needs further investigation on the dynamics of ecosystem functions, including interactions between the human and physical, biological and cultural phenomena. There is a need to apply process based approach that incorporates agricultural production and ecosystem benefits within the context of a linked socio-ecological system and which directly focuses on the causality from change in ecosystem benefits to human well-being and provides a robust basis for decision-making.

♦ Farming systems based research and extension approaches are crucial to deal with complex adaptive systems of local farming systems that have co-evolved with human societies to fit local ecological conditions and satisfy human needs; thus, for technology development, it is important to utilize farmers‘ knowledge, to search for the satisfaction of local people‘s objectives and to actively engage farmers in experimentation and technology design. Intensification of participatory agriculture such as agroforestry, plant breeding and nature protection need to be instituted in the weredas.

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9. APPENDICES

Annex 1 Land area distribution of agricultural crops (ha)

Wereda	Kebele	Total Landsize (ha)	Land area distribution for different agricultural crops (ha)																
			Wheat	Barley	Maize	Harricot bean	TEF	Sorghum	Fieldpea	Beans	Onion	Linseed	Potato	Rape seed	Oats	NOUG	Chickpea	Grasspea	Total
Dodota	Dodota Alem	48.50	20.25	10.25	5.13	4.50	9.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**49.38**
	B/Betala	51.50	12.75	6.75	4.50	6.00	14.25	0.00	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**44.75**
	Awash Bishola	40.75	8.75	9.00	1.75	1.75	16.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	**38.00**
	Sub-Total	**140.75**	**74.75**	**43.00**	**21.00**	**22.75**	**63.75**	**0.00**	**1.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**226.25**
	Aver.	**3.13**	**1.66**	**0.96**	**0.47**	**0.51**	**1.42**	**0.00**	**0.02**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**5.03**
	STDEV	**5.55**	**5.84**	**1.77**	**1.80**	**2.16**	**3.82**	**0.00**	**0.29**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**5.72**
Lode-Hetossa	Tulu Jabi	21.25	6.50	9.25	0.13	0.00	1.38	0.00	0.00	4.13	0.75	1.75	0.00	0.00	0.00	0.00	0.00	0.00	23.88
	Fursa	30.63	27.13	4.38	0.00	0.25	3.50	0.00	0.00	0.00	3.00	0.00	1.43	0.00	0.00	0.00	0.00	0.00	39.68
	Adamare	32.50	28.75	5.75	1.25	0.00	4.00	0.00	0.00	0.00	6.25	0.00	0.13	0.00	0.00	0.00	0.00	0.00	46.13
	Sub-Total	**84.38**	**96.00**	**33.00**	**1.50**	**0.50**	**13.75**	**0.00**	**0.00**	**8.25**	**13.75**	**3.50**	**2.98**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**173.23**
	Aver.	**1.88**	**2.13**	**0.73**	**0.03**	**0.01**	**0.31**	**0.00**	**0.00**	**0.18**	**0.31**	**0.08**	**0.07**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**3.85**
	STDEV	**6.03**	**12.40**	**2.51**	**0.69**	**0.14**	**1.39**	**0.00**	**0.00**	**2.38**	**2.77**	**1.01**	**0.79**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**11.45**
Tiyo	Gora Silingo	48.13	28.50	0.50	2.56	0.00	6.00	1.50	0.25	2.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	41.69
	Burka Chilalo	43.51	9.00	16.75	0.13	0.00	0.00	0.00	4.00	4.00	0.00	0.00	1.88	2.75	0.75	0.00	0.00	0.00	39.25

	Tullu Kuche	38.80	26.80	0.63	2.25	0.25	12.00	1.75	2.00	2.63	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.00	48.80
	Total	**131.94**	**101.80**	**35.13**	**7.63**	**0.25**	**24.00**	**4.75**	**10.50**	**15.38**	**0.00**	**0.00**	**3.75**	**5.50**	**1.50**	**0.50**	**0.00**	**0.00**	**210.68**
	Aver.	**2.93**	**2.26**	**0.78**	**0.17**	**0.01**	**0.53**	**0.11**	**0.23**	**0.34**	**0.00**	**0.00**	**0.08**	**0.12**	**0.03**	**0.01**	**0.00**	**0.00**	**4.68**
	STDEV	**4.67**	**10.80**	**9.35**	**1.33**	**0.14**	**6.00**	**0.95**	**1.88**	**0.88**	**0.00**	**0.00**	**1.08**	**1.59**	**0.43**	**0.29**	**0.00**	**0.00**	**4.96**
Digelu-Tijo	Sagure Mole	52.25	19.25	10.75	0.00	0.00	0.00	0.00	1.70	4.25	0.00	5.75	0.00	0.00	0.00	0.00	1.13	0.75	43.58
	K/ Murkicha	42.50	12.00	3.75	0.00	0.00	0.25	0.00	0.50	1.25	0.00	3.50	0.00	0.00	0.00	0.00	0.00	0.00	21.25
	Shaldo Jigessa	31.40	13.78	7.28	0.50	0.00	0.00	0.00	0.63	2.50	0.00	1.25	0.13	0.00	0.00	0.00	0.00	0.00	26.05
	Sub-Total	**126.23**	**76.28**	**36.28**	**0.50**	**0.00**	**0.50**	**0.00**	**5.03**	**13.50**	**0.00**	**19.75**	**0.13**	**0.00**	**0.00**	**0.00**	**2.25**	**1.50**	**155.70**
	Aver.	**2.81**	**1.70**	**0.81**	**0.01**	**0.00**	**0.01**	**0.00**	**0.11**	**0.30**	**0.00**	**0.44**	**0.00**	**0.00**	**0.00**	**0.00**	**0.05**	**0.03**	**3.46**
	STDEV	**10.43**	**3.78**	**3.50**	**0.29**	**0.00**	**0.14**	**0.00**	**0.66**	**1.51**	**0.00**	**2.25**	**0.07**	**0.00**	**0.00**	**0.00**	**0.65**	**0.43**	**11.75**
	G.Total	**483.29**	**348.83**	**147.40**	**30.63**	**23.50**	**102.00**	**4.75**	**16.53**	**37.13**	**13.75**	**23.25**	**6.85**	**5.50**	**1.50**	**0.50**	**2.25**	**1.50**	**765.85**
	Aver.	**2.68**	**1.94**	**0.82**	**0.17**	**0.13**	**0.57**	**0.03**	**0.09**	**0.21**	**0.08**	**0.13**	**0.04**	**0.03**	**0.01**	**0.00**	**0.01**	**0.01**	**4.25**
% to the HHs' land size			**72.2**	**30.5**	**6.3**	**4.9**	**21.1**	**1.0**	**3.4**	**7.7**	**2.8**	**4.8**	**1.4**	**1.1**	**0.3**	**0.1**	**0.5**	**0.3**	

Annex 2. Recorded agricultural crop species

No.	Species name	Family	Vernacular name		English nam
			Afaan oromo	Amharic	
A	**Cereals**				
5	*Eragrostis tef* (Zucc.) Trotter	Poaceae	Tafi	Tef	TEF
1	*Hordeum vulgare* L.	Poaceae	Garbu	Gebs	Barely
4	*Sorghum bicolor* (L.) Moench	Poaceae	Mishinga	mashila	Sorghum
3	*Triticum aestivum L.*	Poaceae	Aja	Aja	Oats
6	*Triticum dicoccon* Schrank.	Poaceae	Kamadi	Sinde	Wheat
2	*Zea mays* L.	Poaceae	Bokolo	Bekolo	Maize
B	***Pulses***				
7	*Cajanus cajan* (L.) Mill.	Fabaceae		Yewof ater	Pigeon pea
1	*Cicer arietinum* L.	Fabaceae	Shumbura	Shimbra	Chickpea
8	*Glycine max* (L.) Merr.	Fabaceae		Akuri ater	Soybeans
5	*Lathyrus sativus* L.	Fabaceae	Gaya	Guaya	Grasspea
9	*Lens culinaris* Med.	Fabaceae	Misira	Misir	Lentils
6	*Phaseolus vulgaris* L.	Fabaceae		Adenguare	Haricot bean
4	*Pisum sativum* L.	Fabaceae	Atara	Ater	Field peas
3	*Vicia faba* L.	Fabaceae	Bakela	Bakela	Faba beans
2	*Vigna unguiculata*	Fabaceae		Fasolia	Cowpea
C	**Oil seed**				
1	*Brassica carinata* A. Br.	Brassicaceae	Gomanzara	Gomenzer	Rapeseed
2	*Guizotia abyssinica* (L. Fil.) Cases	Asteraceae	Noug	Noug	NOUG
3	*Linum usitatissimum* Linn.	Linaceae	Talba	Telba	Linseed
4	*Ricinus communis* L.	Euphorbiaceae	Kobo	Gulo	Castor beans
5	*Carthamus tinctorius* L.	Asteraceae	Sufi	Suf	Safflower
D	**Roots and Tubers**				
1	*Coccinia* abyssinica (Lam.) Cogn.	Cucurbitaceae	Anchote	Anchote	ANCHOTE
2	*Ensete ventricosum* (Welw.) Cheesman	Musaceae	Warke/koba	Enset	ENSET
3	*Manihot esculenta* Cranz.	Euphorbiaceae	Kasava	Kasava	Cassava
4	*Solanum tuberosum* L.	Solanaceae	Dinicha	Dinch	Potato
E	**Spices and condiments**				
1	*Capsicum frutescens* L.	Solanaceae	Barbare	Berberie	Hot pepper
2	*Rhamnus prinoides* L'Herit	Rhamnaceae	Geshe	Gesho	Rhamnus
3	*Rosmarinus officinalis* L.	Lamiaceae		Siga metibesha	Rose mary
4	*Ruta chalepensis* L.	Rutaceae	Tenaadami	Tenaadam	Rue
F	**Stimulants**				
1	*Catha edulis* (Vahl.) Forssk. ex. Endl.	Celastraceae	Jima	Chat	Khat

2	*Coffea arabica* L.	Rubiaceae	Buna/Kawa	Buna	Coffee
3	*Nicotiana tobacum* L.	Solanaceae	Timbo	Timbaho	Tobacco
G	**Vegetables**				
1	*Allium cepa* L.	Alliaceae	Shinkurti adi	nech shinkurt	garlic, shallo
2	*Allium sativum* L.	Alliaceae	Shinkurti dima	Key shinkurt	Onion
3	*Brassica oleracea* L.	Brassicaceae		Tikilgomen	Cabbage
4	*Lycopersicon esculentum* Mill.	Solanaceae	Timatim	Timatim	Tomato
5	*Saccharum officinarum* L.	Poaceae	Shankora agda	Shenkora ageda	Sugar cane
H	**Fruits**				
1	*Carica papaya* L.	Caricaceae	Papaya	Papaya	Papaya
2	*Casimiroa edulis* La Llve	Rutaceae	Kazamiro	Kazmir	White sapot
3	*Citrus sinensis* (L.) Osheck.	Rutaceae	Birtukana	Birtukan	Sweet orang
4	*Citrus aurantifolia* (Christm.) Wingle	Rutaceae	Lomi	Lomi	Lemon
5	*Mangifera indica* L.	Anacardiaceae	Mango	Mango	Mango
6	*Musa x paradisiaca* L.	Musaceae	Muzi	Muz	Banana
7	*Persea americana* Mill.	Lauraceae	Avokado	Avokado	Avocado
8	*Psidium guajava* L.	Myrtaceae	Zaytuna	Zeyitun	Guajava

Annex 3. List of tree and shrub species

NO.	Scientific name	Family	Vernacular name		Common/English name
			Afan Oromo	Amharic	
1	*Acacaia albida* Del.	Fabaceae	Garbi	Grar	Apple-rig acacia
2	*Acacia abyssinica* Hochst. ex Benth.	Fabaceae	Ambo	Bazra-girar	Umbrella thorn
3	*Acacia etbaica* Schweinf.	Fabaceae	Dodoti	Grar	
4	*Acacia gerrardii* Benth.	Fabaceae	Dare		
5	*Acacia lahai* Steud. & Hochst. ex Benth	Fabaceae	Burquqe/sondi	Wttie	Red thron
6	*Acacia mellifera* (Vahl) Benth.	Fabaceae	Harangama	Kontir	
7	*Acacia nilotica* (L.) Willd. ex Del.	Fabaceae	Kassale	Cheba	Egyptian thorn
8	*Acacia saligna* (Labill) Wendl.	Fabaceae	Akach saligna	Akacha girar	Port Jackson willow
9	*Acacia senegal* (L.) Willd.	Fabaceae	Sapessa/Sebansa dima	Kontir	Gum arabic
10	*Acacia seyal* Del.	Fabaceae	Wachu (Wako-dima	Wachu	White-galled acacia
11	*Acacia tortilis* (Forssk.) Hayne	Fabaceae	Tedecha/Toloba	Deweni grar	
12	*Acanthus sennii* Chiov.	Acanthaceae	Sokoru	Koshoshila	
13	*Acokanthera schimperi* (DC.) Oliv.	Apocynaceae	Kararu	Merenz	Poison-arrow tree
14	*Agarista salicifolia* (Comm. ex Lam.)Don	Ericaceae	Sotira	Koba	
15	*Arundinaria alpina* K. Schum.	Poaceae	Leman	Kerkeha	Mountain bamboo
16	*Balanites aegyptiaca* (L.) Del.	Balanitaceae	Badano	Bedeno	Desert date
17	*Bersama abyssinica* Fresen.	Melianthaceae	Lolichisa	Azamir	Winged bersama
18	*Buddleja polystachya* Fresen.	Loganiaceae	Kawusa	Anfar/Atiquare	
19	*Calpurnia aurea* (Ait.) Benth.	Fabaceae	Chekata	Degita	
20	*Carica papaya* L.	Caricaceae	Papya	Papaya	Papaya
21	*Carissa spinarum* L.	Apocynaceae	Hagamsa	Agam	Carissa plum

22	*Casimiroa edulis* La Llve	Rutaceae	Kazamiro	Kazamir	White sapote
23	*Casuarina cunninghamiana* Miq.	Casuarinaceae	Shawshawe	Arzelibanos	Australian beefwood
24	*Catha edulis* (Vahl.) Forssk. ex Endel.	Celastraceae	Jima	Chat	Khat
25	*Celtis africana* Burn. F.	Ulmaceae	Amalaka/motakoma	Kawut	
26	*Cytisus palmensis* (Christ) Hutch.	Fabaceae		Tree lucern	Tree lucerne, Tagasaste
27	*Citrus aurantifolia* (Christm.) Wingle	Rutaceae	Lomi	Lomi	Lime
28	*Citrus sinensis* (L.) Osheck.	Rutaceae	Birtukana	Birtukan	Sweet orange
29	*Coffea arabica* L.	Rubiaceae	Kawa/buna	Buna	coffee
30	*Cordia africana* Lam.	Boraginaceae	Wadessa	Wanza	Sudan teak
31	*Croton macrostachyus* Hochst. ex Del.	Euphorbiaceae	Bakanisa	Bisana	
32	*Cupressus lusitanica* Mill.	Cupressaceae	Gatira faranji	Ye ferenj Tid	Mexican cypress
33	*Delonix regia (*Boj. ex Hook) Raf.	Fabaceae		Ye Dire dawa Konjo	Flamboyant
34	*Dichrostachys cinerea* (L.) Wight & AM.	Fabaceae	Hate/jeremme	Ader, Ergett-dimmo	
35	*Discopodium penninervium* Hochst.	Solanaceae	Chongi	Amararo	
36	*Dodonaea angustifolia* L.f.	Sapindaceae	Itacha	Kitkita	Hop bush
37	*Dombeya torrida* (J.F.Gmel.) Bamps	Sterculiaceae	Danisa	Wulkifa	
38	*Dovyalis abyssinica* (A. Rich) Warb.	Flacourtiaceae	Koshomi	Koshim	Kei apple
39	*Dracaena afromontana* Mildbr.	Agavaceae	Rukessa		
40	*Ehretia cymosa* Thonn.	Boraginaceae	Ulaga	Game	
41	*Ekebergia capensis* Sparrm.	Heliaceae	Sombo	Lol	
42	*Erica arborea* L.	Ericaceae	Garamba	Asta	Giant heath
43	*Erythrina brucei* Schweinf.	Fabaceae	Walensu	Korch	
44	*Eucalyptus camaldulensis* Dehn.	Myrtaceae	Bargamo dima	Key Bahr-zaf	Red river gum

45	*Eucalyptus globulus* Labill.	Myrtaceae	Bargamo Adi	Nech bahr-zaf	Tasmanian blue gum
46	*Euclea racemosa* Murr. subsp. *schimperi* (A.DC.) Dandy	Ebenaceae	Miessa	Dedeho	
47	*Euphorbia candelabrum* Trem. & Kotschy.	Euphorbiaceae	Adami	Kulkuwal	Candelabra euphorbia
48	*Euphorbia tirucalli* L.	Euphorbiaceae	Anno	Kinchib	Finger euphorbia
49	*Ficus sur* Forssk.	Moraceae	Harbu	Sholla	Cape fig
50	*Ficus vasta* Forssk.	Moraceae	Qiltu	Warka	Sycamore fig
51	*Grevillea robusta* A. Cunn. ex. R. Br.	Proteaceae		Temenja zaf	Silky oak
52	*Grewia trichocarpa* A. Rich.	Tiliaceae	Haroresa		
53	*Hagenia abyssinica* (Bruce) J.F. Gmel.	Rosaceae	Heto	Kosso	Hagenea
54	*Hallea rubrostipulata* (K. Schum.) J.-F. Leroy	Rubiaceae	Buniti		
55	*Hypericum revolutum* Vahl	Hypericaceae	Hinde	Amija	Curry bush
56	*Juniperus procera* Hochst. ex Endl.	Cupressaceae	Gatira	Tid	African pencil cedar
57	*Justicia schimperiana* (Hochst. ex Nees) T. Anders.	Acanthaceae	Umuga	Sensel	
58	*Leucaena leucocephala* (Lam.) Dewit	Fabaceae		Lukina	Leucaena
59	*Lippia adoensis* Hochst. ex Walp	Verbenaceae	Sukaye	Kasse	
60	*Maesa lanceolata* Forssk.	Myrsinaceae	Abayi	Qalawa	
61	*Malus sylvestris* Barnchy	Rusaceae	Pome	Pome	Apple
62	*Mangifera indica* L.	Anacardiaceae	Mango	Mango	Mango
63	*Maytenus undata* (Thunb.) Blakelack	Celastraceae	Kombolcha	Hatat	
64	*Melia azedarach* L.	Meliaceae		Nim	Persian lilac
65	*Moringa stenopetala* (Bak.) Cuf.	Moringaceae		Shiferaw/alako	Cabbage tree
66	*Myrica salicifolia* A. Rich.	Myricaceae	Reji	Shinet, kalava	
67	*Myrsine africana* L.	Myrsinaceae	Kachama		

68	*Myrsine melanophloeos* (L) R.Br.	Myrsinaceae	Tula		
69	*Ocimum gratissimum* L.	Lamiaceae	Bokolu	Damakasse	
70	*Olea europaea* L. subsp. *Cuspidata* (Wall. ex G.Don) Cif.	Oleaceae	Ejersa	Wayira	African wild olive
71	*Persea americana* Mill.	Lauraceae	Abokado	Avokado	Avocado
72	*Phoenix reclinata* Jack.	Arecaceae	Meti	Zenbaba	Wild date palm
73	*Phytolacca dodecandra* L' Herit.	Phytolaccaceae	Andode	Endod	
74	*Pittosporum viridiflorum* Sims	Pittosporaceae	Sole	Lowey	
75	*Podocarpus falcatus* (Thunb.) Mirb.	Podocarpaceae	Birbirsa	Zigiba	Podo
76	*Premna schimperi* Engl.	Lamiaceae	Urgesa	Chocho	
77	*Prunus africana* (Hool.f.) Kalkm.	Rosaceae	Gura	Tiku inchet	Iron wood
78	*Psidium guajava* L.	Myrtaceae	Zaytuna	Zeyitun	Guava
79	*Psydrax schimperiana* (A. Rich.) Bridson	Rubiaceae	Gotole/Seghed		
80	*Pterolobium stellatum* (Forssk.) Brenan	Fabaceae	Kantafa		
81	*Rhamnus prinoides* L' Herit.	Rhamnaceae	Geshe	Gesho	Rhamnus
82	*Rosa abyssinica* Lindley	Rosaceae		Kega	Abyssinian rose
83	*Rubus apetalus* Poir.	Rosaceae	Enjori	Gora	
84	*Schefflera volkensii* (Engl.) Harms	Aroliaceae	Ansha		
85	*Schinus molle* L.	Anacardiaceae	Turimanturi	Kundo barbare	Pepper tree
86	*Sclerocarya birrea* (A. Rich.) Hochst.	Anacardiaceae	Didiksa		
87	*Sesbania sesban* (L.) Merr.	Fabaceae	Ichini	Sasbania	River bean
88	*Spathodea campanulata* subsp. *nilotica* Pal.	Bignoniaceae		Ye chaka nebelbal	Flame tree
89	*Vernonia amygdalina* Del.	Asteraceae	Ebicha	Grawa	Tree vernonia/Bitter leaf
90	*Ziziphus mauritiana* Lam.	Rhamnaceae	Kurkura	Kurkura	Jujube

Annex 4. Distribution of species in the studied weredas (1= present; 0 =absent)

No.	Species	Wereda				
		Dodota	Lode-Hetossa	Tiyo	Digelu-Tijo	Occurrence %
1	*Acacaia albida*	1	1	0	0	50
2	*Acacia abyssinica*	1	1	1	1	100
3	*Acacia etbaica*	1	1	0	0	50
4	*Acacia gerrardii*	1	1	0	0	50
5	*Acacia mellifera*	0	1	1	0	50
6	*Acacia nilotica*	1	0	0	0	25
7	*Acacia saligna*	1	1	1	1	100
8	*Acacia senegal*	1	1	0	0	50
9	*Acacia seyal*	1	0	0	0	25
10	*Acacia tortilis*	1	1	1	0	75
11	*Acanthus sennii*	0	1	0	0	25
12	*Acokanthera schimperi*	1	1	0	0	50
13	*Agarista salicifolia*	0	0	1	0	25
14	*Arundinaria alpina*	0	0	1	0	25
15	*Balanites aegyptiaca*	1	0	0	0	25
16	*Bersama abyssinica*	0	0	1	0	25
17	*Buddleja polystachya*	0	1	1	0	50
18	*Calpurnia aurea*	1	1	1	0	75
19	*Carica papaya*	1	0	0	0	25
20	*Carissa spinarum*	0	1	1	0	50
21	*Casimiroa edulis*	0	1	0	0	25
22	*Casuarina cunninghamiana*	1	1	1	1	100
23	*Catha edulis*	0	1	0	0	25
24	*Celtis africana*	0	1	0	0	25
25	*Cytisus palmensis*	0	0	1	1	50
26	*Citrus aurantifolia*	1	1	0	0	50
27	*Citrus sinensis*	1	0	1	0	50
28	*Coffea arabica*	1	1	1	0	75
29	*Cordia africana*	1	1	1	1	100
30	*Croton macrostachyus*	1	1	1	0	75
31	*Cupressus lusitanica*	0	1	1	1	75

32	*Dichrostachys cinerea*	1	0	0	0	25
33	*Discopodium penninervium*	0	0	1	0	25
34	*Dodonaea angustifolia*	0	1	0	0	25
35	*Dombeya torrida*	0	0	1	0	25
36	*Dovyalis abyssinica*	1	1	1	0	75
37	*Dracaena afromontana*	1	0	0	0	25
38	*Ehretia cymosa*	1	0	0	0	25
39	*Ekebergia capensis*	0	0	1	0	25
40	*Erica arborea .*	0	0	1	1	50
41	*Erythrina brucei*	0	1	0	0	25
42	*Eucalyptus camaldulensis*	1	1	0	0	50
43	*Eucalyptus globulus*	0	1	1	1	75
44	*Euclea racemosa* subsp. *schempri*	0	1	0	0	25
45	*Euphorbia candelabrum*	0	1	1	0	50
46	*Euphorbia tirucalli*	1	1	0	0	50
47	*Ficus sur*	1	1	1	1	100
48	*Ficus vasta*	1	1	1	0	75
49	*Grevillea robusta*	1	1	0	0	50
50	*Grewia trichocarpa*	1	0	0	0	25
51	*Hagenia abyssinica*	1	1	0	1	75
52	*Hypericum revolutum*	0	0	1	0	25
53	*Juniperus procera*	0	1	1	1	75
54	*Justicia schimperiana*	1	1	1	1	100
55	*Leucaena leucocephala*	1	0	1	0	50
56	*Lippia adoensis*	0	1	0	0	25
57	*Maesa lanceolata*	0	1	1	0	50
58	*Malus sylvestris*	0	0	1	0	25
59	*Mangifera indica*	1	0	0	0	25
60	*Maytenus undata*	0	1	1	1	75
61	*Melia azedarach*	1	1	1	0	75
62	*Hallea rubrostipulata*	1	0	0	0	25
63	*Moringa stenopetala*	1	0	0	0	25
64	*Myrica salicifolia*	0	0	0	1	25
65	*Myrsine africana*	0	1	1	0	50
66	*Myrsine melanophloeos*	0	0	1	0	25

67	*Ocimum gratissimum*	1	0	1	0	50
68	*Olea europaea* subsp.*cuspidata*	1	1	1	1	100
69	*Persea americana*	0	0	1	0	25
70	*Phoenix reclinata*	0	0	1	0	25
71	*Phytolacca dodecandra*	0	1	1	0	50
72	*Podocarpus falcatus*	0	1	1	1	75
73	*Premna schimperi*	1	0	0	0	25
74	*Prunus africana*	0	0	1	0	25
75	*Psidium guajava*	0	1	1	0	50
76	*Psydrax schimperanum*	0	1	0	0	25
77	*Pterolobium stellatum*	1	0	0	0	25
78	*Rhamnus prinoides*	0	1	1	1	75
79	*Rosa abyssinica*	0	1	1	0	50
80	*Rubus apetalus*	0	1	1	0	50
81	*Schefflera volkensii*	0	0	1	0	25
82	*Schinus molle*	1	1	0	1	75
83	*Sclerocarya birrea*	0	1	1	0	50
84	*Sesbania sesban*	1	1	1	1	100
85	*Spathodea campanulata*	0	1	0	0	25
86	*Vernonia amygdalina*	0	1	1	1	75
87	*Ziziphus mauritiana*	1	0	0	0	25

Annex 5. Relative importance values of tree and shrub species

No.	Species	Fuel wood	Construction	Shade	Nitrogen fixation	Food	Animal feed	Windbreak	Medicinal	Income generation	Conservation	Ornamental
1	*Eucalyptus globulus*	**35.6**	**37.8**	2.2	0.6	0.0	0.0	**22.2**	11.1	**30.0**	**13.3**	4.4
2	*Acacia etbaica*	17.8	10.6	13.3	**17.2**	0.0	4.4	0.0	3.9	2.2	7.8	0.0
3	*Schinus molle*	15.0	10.6	1.1	7.2	0.0	0.6	13.3	5.6	0.6	4.4	3.3
4	*Melia azedarach*	12.8	10.0	2.2	7.8	0.0	0.6	0.6	**12.2**	1.1	5.6	5.0
5	*Acacia tortilis*	12.2	8.9	**14.4**	12.8	0.0	6.7	0.0	3.9	1.1	3.9	0.0
6	*Acacia abyssinica*	10.6	7.2	13.9	10.0	0.0	0.6	0.6	0.0	0.6	8.3	0.0
7	*Hagenia abyssinica*	8.3	10.0	6.1	9.4	0.0	6.7	5.6	10.0	7.2	8.3	3.9
8	*Podocarpus falcatus*	8.3	8.3	11.1	10.6	0.0	2.2	1.7	1.7	5.6	6.7	1.7
9	*Croton marostachyus*	7.8	2.2	5.6	13.3	0.0	0.6	3.9	2.2	1.7	6.1	0.6
10	*Juniperus procera*	7.2	7.8	6.1	3.3	0.0	0.0	5.0	0.6	6.1	7.2	3.9
11	*Cordia africana*	6.7	12.8	3.9	11.7	0.0	1.7	4.4	0.6	5.0	5.0	1.1
12	*Acacia saligna*	6.1	2.8	1.1	6.1	0.0	2.2	4.4	0.0	0.0	4.4	0.0
13	*Olea europaea* subsp.*cuspidata*	6.1	6.7	3.3	3.9	0.0	2.8	3.3	4.4	2.8	3.9	2.8
14	*Sesbania sesban*	6.1	5.0	1.7	8.9	0.0	**7.8**	6.7	1.7	0.0	3.9	0.0
15	*Balanites eagyptiaca*	4.4	0.6	6.1	3.9	0.0	1.1	0.0	2.2	0.6	3.9	0.0
16	*Justicia schimperiana*	3.9	6.1	1.1	2.2	0.0	0.6	1.7	0.6	0.6	2.8	0.0
17	*Acacia albida*	3.3	1.1	7.2	7.8	0.0	0.0	0.6	0.0	0.0	1.1	**7.8**
18	*Acacia seyal*	3.3	5.0	3.3	2.2	0.0	1.1	0.0	2.8	0.0	1.7	0.0
19	*Ziziphus mauritiana*	3.3	3.3	5.0	7.2	1.1	3.3	0.0	1.1	0.6	2.2	0.0
20	*Cupressus lusitanica*	2.8	5.0	1.7	1.1	0.0	0.0	2.8	0.0	3.3	2.8	0.6
21	*Ehretia cymosa*	2.8	1.1	1.7	1.7	0.0	0.0	0.0	0.0	0.0	1.7	0.0

22	*Casuarina cunninghamiana*	2.2	3.9	1.1	2.8	0.0	1.1	3.3	0.0	1.7	2.2	1.7
23	*Eucalyptus camaldulensis*	2.2	4.4	0.0	0.0	0.0	0.0	1.7	3.3	1.1	0.0	0.0
24	*Acacia nilotica*	2.2	2.2	5.6	5.0	0.0	1.1	0.0	0.0	0.6	2.2	0.0
25	*Malus sylvestris*	1.7	0.6	0.0	0.6	**3.9**	0.6	3.3	3.3	3.9	2.8	0.0
26	*Dovyalis abyssinica*	1.7	2.2	0.0	3.3	2.2	1.1	5.6	0.0	2.8	4.4	0.0
27	*Vernonia amygdalina*	1.7	2.2	2.2	4.4	2.8	2.8	2.8	1.1	2.2	2.8	0.0
28	*Buddleja polystachya*	1.1	0.6	2.2	1.7	0.0	1.7	0.0	0.0	1.1	0.6	0.0
29	*Grevillea robusta*	1.1	1.1	0.0	0.0	0.0	0.0	0.6	0.0	0.6	0.0	0.6
30	*Ficus vasta*	1.1	1.1	0.6	1.1	0.0	0.0	0.0	0.0	0.0	1.1	0.0
31	*Leucaena leucocephala*	1.1	1.1	0.0	1.7	0.0	2.2	1.1	0.0	0.0	0.6	0.0
32	*Ficus sur*	1.1	1.1	1.1	0.6	0.0	0.0	0.0	0.0	0.0	1.1	0.0
33	*Cytisus palmensis*	1.1	1.1	1.1	1.7	0.6	3.9	1.1	0.0	1.1	0.6	0.0
34	*Hypericum revolultum*	0.6	0.6	1.7	1.7	0.0	0.6	0.0	0.0	0.0	0.0	0.0
35	*Calpurnia aurea*	0.6	0.6	0.0	2.8	0.0	0.0	0.0	0.6	0.0	0.6	0.0
36	*Coffea arabica*	0.6	0.0	0.0	2.2	2.2	0.6	0.6	1.1	3.3	1.7	0.0
37	*Ocimum gratissimum*	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0
38	*Dombeya torrida*	0.6	0.6	0.0	0.6	0.0	0.0	0.6	0.0	0.6	0.6	0.6
39	*Delonix regia*	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
40	*Sclerocarya birrea*	0.6	0.0	1.1	1.1	0.0	0.0	0.0	0.0	0.0	1.1	0.0
41	*Maytenus undata*	0.6	0.6	1.7	1.7	0.0	0.6	0.0	0.0	0.0	0.6	0.0
42	*Dichrostachys cinerea*	0.6	0.6	1.1	1.1	0.0	0.6	0.0	0.0	0.0	0.6	0.0
43	*Maesa lanceolata*	0.6	0.0	1.7	1.7	0.0	0.0	0.0	0.0	0.0	0.6	0.0
44	*Acokanthera schimperi*	0.6	0.6	1.7	1.7	0.0	0.0	0.0	0.0	0.0	0.6	0.0
45	*Pterolobium stellatum*	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0
46	*Ekebergia capensis*	0.6	0.6	1.1	1.1	0.0	0.6	0.6	0.0	1.1	0.6	0.0

47	*Moringa stenopetala*	0.6	0.0	0.0	0.6	1.7	0.6	0.6	0.6	0.6	0.0	0.6
48	*Citrus sinensis*	0.6	0.0	0.0	0.0	1.1	0.0	0.6	0.0	1.1	0.6	0.0
49	*Prunus africana*	0.6	0.6	0.0	0.0	0.0	0.6	0.6	0.0	0.6	0.6	0.6
50	*Myrsine melanophloeos*	0.6	0.6	0.6	0.6	0.0	0.6	0.0	0.0	0.0	0.6	0.0
51	*Acacia senegal*	0.0	0.0	1.1	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
52	*Discopodium penninervium*	0.0	0.0	0.6	1.1	0.0	0.6	0.6	0.0	0.6	0.6	0.0
53	*Persea americana*	0.0	0.0	0.0	0.0	0.6	0.0	0.6	0.0	0.6	0.0	0.0
54	*Rubus apetalus*	0.0	0.0	0.0	0.6	0.6	0.0	0.0	0.0	0.6	0.6	0.0
55	*Rhamnus prinoides*	0.0	0.0	0.0	0.0	0.6	1.1	1.7	1.1	2.2	1.7	0.0
56	*Grewia trichocarpa*	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
57	*Casimiroa edulis*	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.6	0.0	0.0
58	*Arundinaria alpina*	0.0	0.6	0.0	0.0	0.0	0.0	0.6	0.0	0.6	0.6	0.6
59	*Citrus aurantifolia*	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.6	0.0	0.0
60	*Mangifera indica*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0
61	*Carica papaya*	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.6	1.7	0.0	0.0
62	*Spathodea campanulata*	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6
63	*Phoenix reclinata*	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.6	0.6	0.0
64	*Psidium guajava*	0.0	0.0	0.0	0.0	0.6	0.6	0.6	0.0	0.6	0.6	0.0

Annex 6. Use-values of tree and shrub species

No.	Species	Dodota	Lode-hetossa	Tiyo	Digelu-Tijo
1	*Acacia abyssinica*	0.00	**1.16**	**0.82**	0.00
2	*Acacia albida*	0.40	0.29	0.00	0.00
3	*Acacia etbaica*	**0.89**	0.47	0.00	0.00
4	*Acacia nilotica*	0.76	0.00	0.00	0.00
5	*Acacia saligna*	**0.73**	0.31	0.00	0.00
6	*Acacia senegal*	0.09	0.00	0.00	0.00
7	*Acacia seyal*	0.76	0.00	0.00	0.00
8	*Acacia tortilis*	2.56	0.00	0.00	0.00
9	*Acokanthera schimperi*	0.20	0.00	0.00	0.00
10	*Arundinaria alpina*	0.00	0.00	0.11	0.00
11	*Balanites eagyptiaca*	**0.87**	0.00	0.00	0.00
12	*Buddleja polystachya*	0.00	0.00	0.36	0.00
13	*Calpurnia auea*	0.16	0.04	0.00	0.00
14	*Carica papaya.*	0.11	0.00	0.00	0.00
15	*Casimiroa edulis*	0.00	0.04	0.00	0.00
16	*Casuarina cunninghamiana*	0.07	0.38	0.36	0.00
17	*Citrus auriantifolia*	0.04	0.00	0.00	0.00
18	*Citrus sinensis*	0.04	0.00	0.11	0.00
19	*Coffea arabica*	0.07	0.33	0.09	0.00
20	*Cordia africana*	0.11	**1.51**	0.42	0.00
21	*Croton macrostachyus*	0.40	**1.18**	0.11	0.00
22	*Cupressus lusitanica*	0.00	0.42	0.04	0.29
23	*Cytisus palmensis*	0.00	0.00	0.33	0.16
24	*Delonix regia*	0.00	0.02	0.00	0.00
25	*Discopodium penninervium*	0.00	0.00	0.16	0.00
26	*Dombeya torrida*	0.00	0.00	0.16	0.00
27	*Dovyalis abyssinica*	0.07	**0.73**	0.09	0.00
28	*Ehretia cymosa*	0.33	0.00	0.00	0.00
29	*Ekebergia capensis*	0.00	0.00	0.24	0.00
30	*Eucalyptus camaldulensis*	0.04	0.33	0.00	0.00
31	*Eucalyptus globulus*	0.00	**0.96**	**2.47**	**2.71**
32	*Ficus sur*	0.00	0.00	0.20	0.00
33	*Ficus vasta*	0.00	0.00	0.20	0.00
34	*Grevillea robusta*	0.11	0.04	0.00	0.00

35	*Grewia trichocarpa*	0.02	0.00	0.00	0.00
36	*Hagenia abyssinica*	0.00	0.22	**2.47**	0.31
37	*Hypericum revolutum*	0.00	0.00	0.16	0.00
38	*Juniperus procera*	0.00	0.16	**1.53**	0.16
39	*Justicia schimperiana*	0.09	**0.64**	0.07	0.00
40	*Leucaena leucocephala*	0.38	0.00	0.00	0.00
41	*Malus sylvestris*	0.00	0.00	**0.73**	0.00
42	*Mangifera indica .*	0.02	0.00	0.00	0.00
43	*Maytenus undata*	0.00	0.00	0.22	0.00
44	*Maesa lanceolata*	0.00	0.00	0.18	0.00
45	*Melia azedarach*	**2.27**	0.33	0.16	0.00
46	*Moringa stenopetala*	0.18	0.00	0.00	0.00
47	*Ocimum gratissimum.*	0.04	0.00	0.00	0.00
48	*Olea europaea* sbsp. *cuspidata*	0.13	0.11	1.36	0.00
49	*Persea americana*	0.00	0.00	0.07	0.00
50	*Phoenix reclinata*	0.00	0.00	0.07	0.00
51	*Podocarpus falcatus*	0.00	0.02	**2.29**	0.00
52	*Prunus africana*	0.00	0.00	0.16	0.00
53	*Psidium guajava*	0.00	0.00	0.11	0.00
54	*Pterolobium stellatum*	0.04	0.00		0.00
55	*Myrsine melanophloeos*	0.00	0.00	0.13	0.00
56	*Rhamnus prinoides*	0.02	0.00	0.31	0.00
57	*Rubus apetalus*	0.00	0.00	0.09	0.00
58	*Sclerocarya birrea*	0.00	0.00	0.13	0.00
60	*Sesbania sesban*	**1.27**	0.18	0.20	0.02
61	*Schinus molle*	**1.93**	0.49	0.00	0.00
62	*Spathodea campanulata subsp. nilotica*	0.00	0.02	0.00	0.00
63	*Vernonia amygdalina*	0.00	**0.69**	0.16	0.00
64	*Ziziphus mauritiana*	**1.11**	0.00	0.00	0.00

Annex 7. Questionnaire for households' socio economic survey

Date:_____Region: _____________ Zone: _________ Wereda: ________

Kebele: ________. Village: _______Name of Interviewer: ____________

1. HOUSEHOLD CHARACTERISTICS

1.1. Name of the household's name: ______Sex: 1. Male: __2. Female: _____
1.2. Age: __Religion: 1. Orthodox____2. Protestant __3. Muslim___4. Other __
1.3. Martial status: 1. Single: __2. Married: __3: Divorced: __ 4. Widowed:__
1.4. Family size: 1. Male: _____ 2. Female: _____ 3. Total: _________
1.5. Family members' age: 1. less than 15 yrs. __2. 15 – 64 yrs: _3. Above 64 yrs: _.
1.6. Ethnic group: 1. Oromo ___ 2. Amhara ___ 3. Gurage ____ 4. others___
1.7. Education level: (a) Illiterate (b) Read and write (c) Grade 1-8 (d) Grade 9-12: (e) >12 gr.
1.8. Were you borne here? 1. Yes______ 2. No___________
1.9. If no, how long have you lived in this place? 1. <10 yrs. __2. 10 – 20 yrs _ 3. > 20 yrs

2 LAND USE SYSTEM/LAND USE PATTERN

Total landholding _____ .Total area under cultivation _____ of which:

a) Annual crop ___ha; b) Perennial crop ___ha .c) Fallow ___ ha.
d) Pasture /grazing (private) __ha. e) Woodlot ___ ha. f) Others/specify __ ha.

3. SOCIO-ECONOMIC ISSUES

3.1 Income and Expenditure

3.1.1 Source of family income

Sources of income	Rank	%	Qty.	Birr
Marketing of crops				
Marketing of livestock				
Livestock products				
Fuelwood				
Round/split wood				
BLT				
Charcoal				
Crop residue (fuel)				
Dung cakes				
Production & sale of lumber/timber (pit sawing)				
Trading				
Handicraft				
Others/specify				

3.1.2.Does any member of your family have off-farm employment? 1. Yes __2. No _

3.1.3 If yes, fill the following:

Employment status	No. of persons	Income per year
Full-time		
Part time		
Self employed		
Seasonal employment		
Unemployed		

3.1.4 What is the current gross/combined annual income of the household?

Income range	Please mark (√)	Remarks
Under Birr 500		
>Birr 500 - 1000		
>Birr 1000-1500		
>1500 – 2000		
Above 2000		

3.1.4.1 Does the household receive additional income from any source?1. Yes __2. No _

3.1.4.2 Approximately, how much additional income does the household receive each year? ___

3.1.4.3 What are the sources of the additional income? (1) off-farm employment (2) petty trade (3) remittance (4) any other, specify____________

3.1.4.4 How much cash income did different members of your family made from various activities?

Sources of income	Annual income (Birr)
Salary	
Income from milk, butter, cheese, eggs, etc.	
Vegetable sales	
Fruit sales	
Wage income from temporary work	
Income from livestock and poultry sales	
Income from honey	
Sales of other crops (wheat, barely, corn, etc.)	
Handcrafts sales	
Money sent from family members outside /remittances	

Rental income from different properties (horse rent, farmland lease, etc.)	

3.3.13 Source of farm labor working full time on the farm

Source	**No. of members age 10 & above**
Household members	
♦ male	
♦ female	
Hired labor	
♦ male	
♦ Female	
Communal/traditional labor	
♦ Male	
♦ female	
Others specify	

3.1.4.5 How much do you spend per year on the following?

Description	Range in Ethiopian Birr				
	0	1	2	3	4
	Not app.	1-500	>500-1000	>1000-1500	>1500
School					
Food					
Clothing (shoes, dress, etc.)					
Medication					
Telephone					
Animal feed					
Agricultural inputs (fertilizer, herbicides, pesticides,)					
Contract labor					
Social contribution (Idir, etc.)					
Household items					
Veterinary expenses					

Land lease					
Income tax					

3.1.4.6 How many kg do you produce and how many kg do you purchase?

Item	Total amount of consumption	Amount produced	Amount purchased
Meat			
Chicken			
Milk			
Oil			
Sugar			
Legume (beans, chickpea, potato, etc.)			
Cereals (flour, etc.)			
Fresh vegetable			
Fruit			
Honey			
Salt			
Others, (specify)			

3.1 .2 Forest development and conservation issues

3.1.2.1 What are the main species growing in different land use systems in your vicinity? (1) in homegarden (2) on farm (3) on pastureland (4) woodlot

No.	Species	Homegarden	On farm	pasture	woodlot	Natural forest

3.1.2.2 What the uses of species listed under (Q, 3.1.2.1)?

No.	Species	uses						
		Fast growing	Multipurpose	N-fixation	Fodder	Fuelwood	Only available species	Income generation

3.1.2.3 Do you leave trees on farmland? 1. Yes 2. No

3.1.2.4 If yes, why? (1) For wind break (2) productivity improvement (3) fodder production (4) SWC (5) traditional (6) spiritual (7) any other (specify) _____

3.1.2.5 Which tree or shrub species do you retain on farmlands? (1) Fodder producers (2) productivity improvers (3) shade trees (4) graceful trees (5) non-compete with agriculture (6) any other (specify) ________________.

3.1.2.6 Which of the indigenous species do you retain on farm lands?

No	Tree/shrub species	Purpose of retention		
		Shade	N-fixation	Any other

3.1.2.7 If no. to 3.1.2.3, why ____________________________________

3.1.2.8 Is there any natural forest in your kebele? 1. Yes 2. No

3.1.2.9 If yes, what is the size of the forest area? ________________

3.1.2.10 If your answer is yes to question 3.2.2.8, what are the benefits you get from this forest?
1. Fuelwood collection for home use__2. Grazing __3. Material for construction ____ 4. Non-timber forest products 5. Employment __6. Income from sales of forest products (7) shade and shelter for animals ___

3.1.2.11 Who is responsible to manage the forest? (1) Local communities (2) government (3) both (4) private

3.1.2.12 Do you like the presence of natural forest in this locality? (1) Yes (2) No

3.1.2.13 If No. why ? (1) not useful (2) limit agricultural land expansion (3) not belong to the community (4) create conflict with the government (5) any other reason (specify) __.

3.1.2.14 What are the main indigenous tree/shrub species growing in this forest/locality?

No.	Local name	Type of species		Main uses						
		Tree	shrub	Conservation	Fuelwood	Construction	fodder	Food	shade	medicinal

3.1.2.15 Is the forest in your area (1) increasing (2) decreasing (3) the same

3.1.2.16 If increasing, how? (1) by planting (2) protecting the forest to naturally regenerate (3) by relocating the dwellers from the forest area

3.1.2.17 If decreasing, why? (1) Agricultural land expansion (2) grazing (3) fuelwood collection (4) settlement (5) charcoaling (6) any other (specify)--

3.1.2.18 What are the effects of forest destruction? (1) Soil erosion (2) shortage of fuelwood and construction (3) shortage of fodder (4) loss of traditional medicine (5) change of climate (6) any other (specify)______________

3.1.2.19 Have you ever realized the effect of deforestation on wildlife found in your area? Yes (2) No

3.1.2.20 What do you think to re-vegetate your area? (1) tree planting on farmlands (2) planting in homegarden (3) area closure (4) guarding the remaining forest (5) any other (specify) _

3.1.2.21 What are the uses of having trees on the farmland? (1) Wood's produces (2) fodder (3) food (4) productivity improvement (5) SWC

3.1.2.22 How the tree/shrub improve land productivity? (1) SWC (2) water retention (3) organic matter input (4) fodder (5) manure (6) Any other, (specify)____

3.1.2.23 Do you plant tree/shrub species (practice agroforestry) in your homegarden, on farmland and pastureland? (1) Yes (2) No.

3.1.2.24 From where do you get seedlings? (1) Agriculture and Rural deve't office (2) private (3) own nursery (4) NGOs (5) buying from farmers/private nursery

3.1.2.25 Do you like to expand your plantation? 1. Yes (2) No

3.1.2.26 If yes, why? (1) For productivity improvement (2) provision of forest products (3) environmental protection (4) income generation (5) spiritual reason

Species	Year of planting	No. of trees	Uses									
			Fuelwood	Construction	Fodder	SWC	N-fixing	Medicinal	Windbreak	Food	Ornamental	Cash income

3.1.2.27 Which tree species do you prefer to plant & which place do you prefer for planting?

Species	Place (farmland, pasture, homegarden, etc.)	Reason for place

Codes: Place/location

Homestead:	1	Wasteland:	5
Field boundary/border:	2	conservation structure:	6
Crop fields/arable land:	3	Grazing/pasture:	7
River bank:	4	other places/specify:	8

3.1.2.28 Which tree species do you prefer for the following uses?

Purpose	Species
1. fuelwood	
2. construction	
3. furniture	
4. shade	
5. boundary/live fence	
6. make silo/ storage facility	
7. farm implements	
8. medicinal	
9. human food	
10. fodder	
11. others /specify	

3.1.2.27 Uses/functions of the trees/shrubs(planted or left on-farm)

Species	Uses/functions (tick as appropriate)																					
	1		2		3		4		5		6		7		8		9		10		11	
	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N	Y	N

Note 1: uses/ functions

Note 2:

Y = yes, N = No. 4 = sale 8 = Furniture/Farm implement - Forage/human food = in form of fruits, leaves, etc.

1 = Fuel 5 = Cash crop 9 = Conservation - Construction = in form of lumber, plank, poles, etc.

2 = forage 6 = Medicinal 10 = Furniture/farm implement - Sale = in form of fuelwood, construction materials, etc.

3 = Human food 7 = Construction 11 = Live fence Cash crop (e.g. in form of fruits)

conservation = shade, shelter/wind break, soil fertility, terracing, etc.

3.1.2.28 Where do you collect tree wood for various uses, specify quantity used?

Purpose[1]	Indicate quantity by source					
	1. own land	2. common land	3. Community forest	4. State forest	5. purchase	6. others[2]
1. House construction						
2. Fencing						
3. Furniture						
4. Storage facility						
5. Lumber						
6. Sales						
7. other/specify						

3.1.2.29 Production of trees/shrubs (i.e., planted or left on farm)

Species	Planting	Management	Harvesting

[1] Underline units used (use m3 as far as possible)

[2] others (e.g., NGO, School, etc.)

	Method	source		Method	Rate	
					Time/year	Yrs/tree

Planting/ Sources:

Government = 1

Private/farmer = 2

Own nursery = 3

Market = 4

NGO = 5

School = 6

Church = 7

Others = 8

Management

Pruning = 1

Pollarding = 2

Coppicing = 3

Thinning = 4

others/specify = 5

Harvesting / Method

Collect fallen BLT = 1

Bending = 2

Clear felling = 3

Selective felling = 4

Products/fruits = 5

Others/specify = 6

3.1.3 Crop production

3.1.3.1 Total Area of crop production for this year ____________________ ha.

3.1.3.2 What are the major annual (cereals, pulses &oil) crops grown and production

No.	Crop species	Area (ha)	Total production	Consumed	Sold	Income from sale
1						
2						

3.1.3.3 What are the major perennial crops grown & their annual production

Type of crop	Area			Production	
	No. of trees	Unit	Ha	Local unit	Quintal

No. of trees for perennials (enset, coffee, chat, etc.)

3.1.3.4 What are the major roots and tuber crops grown & production?

Type of crop	Area			Production	
	No. of trees	Unit	Ha	Local unit	Quintal

3.1.3.5 Cropping system/management

3.1.3.6 Which cropping system do you practice? (using belg and meher)

a) Single cropping ____ b) double cropping ______ c) both ______.

b) Do you practice crop rotation? Yes _____; No ___. If yes, which crops?

a) 1. ___________ 2. ________________ b) 1.________ 2. __________

3.1.3.7 Do you practice inter-cropping? Yes _____; No _____.if yes, which crops? a) ____with___; b) ___ with __ c)_______ with____________.

3.1.3.8 Do you practice cultural soil and water conservation measures? Yes _; No. __. If yes, tick as appropriate. (a)Contour ploughing/tillage/seeding (b)Terracing/bunds____ (c) Contour bunds______(d) Diversion ditches ____(e) Tied ridges (f) Others/specify _____

3.1.3.9 Is your land in one single plot or two or more plots located in different area? 1. One-plot _________; 2. Two or more _____________.

3.1.3.10 Do you practice the following types of land lease system: tick as appropriate):

3.1.3.10.1 Do you lease-in land from somebody else, 1. Yes ______ 2. No _______.
If yes, what arrangement do you use?

a) Share cropping ____(b) If rental, how much do you pay? (Br./ha or quintals of crop per hectare)____(c) Other arrangements (specify) ____________

3.1.3.10.2 Do you lease out land to somebody else, 1. Yes _______ 2. No _______.
If yes, what arrangement do you use?

a) Share cropping ___(b) If you rent out, how much do accept? (Birr/ha or quintal/ha_________(c) Other arrangements (specify) ____________.

3.1.3.11 Did you decrease/increase your cultivated land in the last five years?(a)Yes (b) No
If, yes, why, and how 1. Renting/leasing 2. Expansion to fallow land 3. Expansion to forestlands.

3.1.3.12 Agricultural inputs

3.1.3.12.1 Do you use fertilizer? Yes ____; No______.

3.1.3.12.2 If yes, what kind of fertilizer do you use and for which crops?

Fertilizer type	CROP TYPES			
	Teff	Wheat	Barely	
1. Cow dung				
2. Chemical fertilizer				
3. Compost (decay organic residue)				
4. Weed compost (green manure & mulch)				
5. animals night keeping in the field				
6. Others/specify				

3.1.3.12.3 Please indicate crop type & application rate of chemical fertilizer you commonly use and total cost?

Crop type	Rate (qt./ha)	Unit price	Total cost	Rate (qt./ha)	Unit price	Total price
	1. DAP			2. Urea		

3.1.3.13 Do you use improved seed? If yes, how much do you pay for it? (Birr/quintal)

No.	Improved seed crop	Unit	Qty.	Unit price	Total price

3.1.3.14 Where do you get improved seed? (1) MOARD (2) NGO (3) Seed enterprise (4) Farmers/friends

3.1.3.15 How many varieties of each crop do you know so far?

No.	Crop type	No. of varieties	Which of the varieties you use now
1			
2			

3.1.3.16 Do you have traditional varieties of your crops? 1. Yes 2. No.

3.1.3.17 if yes, name the varieties for each crop;

No.	Crop type	No. of varieties	Which of the varieties you use now
1			
2			

3.1.3.18 If no for Q.3.2.13 why? 1. No traditional varieties in the area 2. Lost due to replacement by modern varieties 3. another reason (specify)____________

3.1.3.19 What are the advantageous of using improved varieties? 1. High productivity 2. To satisfy the interest of the government 3. No alternative 4. another (specify) ___

3.1.3.20 What is the disadvantage of using improved varieties? 1. loss of traditional variety 2. Susceptible to disease and pests; 3. No sustainability, 4. Poor taste quality 5. Expensive 6. another (specify) ________________

3.1.3.21 Do you receive improved varieties regularly? 1. Yes 2. No

3.1.3.22 What are the advantages of using local varieties? (1) high production (2) resistant to pest and disease (3) drought tolerant (4) cheaper (5) easy to manage (6) can produce good yield without fertilizer (7) taste and manageability

3.1.3.23 What are the disadvantages of local varieties? (2) Low production (2) poor quality (3) low price (4) any, other (specify) __________________

3.1.3.24 How is the availability of industrial agricultural inputs and improved varieties? (1) always available (2) scarce (3) late delivery (4) always short of demand

3.1.3.25 Which agricultural inputs do you prefer for your agricultural activities? (1) modern agricultural inputs (agrochemicals: fertilizer, herbicides; insecticides, etc.); (2) local inputs (manure, compost, and local crop varieties) (3) both

3.1.3.26 If you use modern agricultural inputs, how have you started using it? (1) voluntarily (2) forced by the government (3) due to low productivity of land (3) any other (specify) ______________________________.

3.1.3.27 How is the trend of your crop production for the last 5 years? (Table__)
1) Increasing 2) decreasing 3) no change

3.1.3.28 Production (yield in quintal) of each agricultural crops over the last five years (2003-2007)

Year	Cereals					pulses						Oil crops			
	Wheat	barely	teff	maize	sorghum	Faba beans	Field peas	Haricot beans	Lentils	chick beans	Soya beans	Linseed	Noug	Rape seed	safflower
2003															
2004															
2005															
2006															
2007															

3.1.3.29 Do your last year's production is sufficient for your family?(a) Yes (b) No

3.1.3.30 If no, what is the reason?
1. Shortage of farm land 2. Shortage of inputs (seed, fertilizers, farm power, etc.) 3. Bad weather 4. Other reasons (specify)

3.1.3.31 If no, how do you manage to fill the gap?
1. Family members sale labor 2. Sale livestock 3. Get remittance 4. Aid from GO and/or NGO 5. Borrowing 6. Other means

3.1.3.32 For how many months of the year do you rely on your produced crops without external support or buying from market?
1. < 3 months 2. 3 – 6 months3. 6 – 9 months4. 9-12 months

3.1.3.33 How many quintals of crops (all types) of food do your family requires for 12 months? ____ qt.

3.1.3.34 Do you use any labor from outside other than your family? 1. Yes _ 2. No ___.

3.1.3.35 What is the share of crop production contribution of your annual income? Estimated percentage ________________ %.

3.1.4 Livestock production

3.1.4.1 Livestock population/production

Type		Total No.
Cattle	Ox	
	Bull	
	Cow	
	Heifer	
	Calf	

Other livestock	Adult		Young		Total No.
	M	F	M	F	
Sheep					
Goats					
Camels					
Horses					
Mules					
Donkeys					
Chickens					

3.1.4.2 What are sources of livestock feed?

Livestock feeding methods (rank from one to five)	Rank	
	Dry	Wet
Natural grazing/free grazing		
Natural grazing/tethered grazing		
Stubble grazing (after harvest)		
Growing forage crops		
Hay/cut and carry		
Tree leaves/fruits		
Others/specify)		

3.1.4.3 Months with shortage of grazing (put tick mark):

Season	J	F	M	A	M	J	J	A	S	O	N	D
Dry												
Wet												

3.1.4.4 What is the share of livestock contribution to your annual income? Estimate the percentage ______________%.

3.1.4.5 Quantify and price of all inputs used in all livestock enterprises last cropping season

Name of the input	Quantity (n the appropriate unit)	Unit price (Birr)

3.1.5 Financial schemes

3.1.5.1 Do you participate in any formal or informal credit scheme/ 1. Yes 2. No

3.1.5.2 For what purpose do you need the credit? 1. Purchasing inputs, like fertilizers, chemicals 2. Purchasing of improved seeds 3. Purchasing household consumables 4. any other (specify) ____________________

3.1.5.3 How much money do you borrow per year for purchase of agricultural inputs? (1) <500 Birr (2) 500-1000 birr (3) 1001-1500 (4) > 1500 Birr

3.1.5.4 Do you borrow money for other purposes other than agricultural inputs? (1) Yes (2) No

3.1.5.5 For what purposes do you borrow? (1) for running business (2) house construction (3) purchase of draught animals (4) purchase of food items

3.1.6 SOCIO - CULTURAL ISSUES

3.1.6.1 How do people get together to discuss on issues of community concerns? (a) Through formal community organization (b)Through iddir (c) Through religious leaders (d)Through esteemed leaders

3.1.6.2 Do you organize or participate in the informal organizations such as Iddir, debo, Wonfel, Mahber and other similar informal social organizations? Yes _; No.___.

3.1.6.3 If yes, state the name of the most important one informal association for which you organize or participate for the tasks mentioned above? a) _____b) _________; c) __________ d) _________.

3.1.6.4 Have you taken part in any of the following community development programmes: (1)Afforestation __(2)Soil and water conservation _; (3) social services (water supply, education, health etc.)____.

3.1.6.5 Is there sex discrimination in this area? (1) Yes _; (2) No.____.

3.1.6.6 Who is the decision maker on the household assets (land, livestock) in your household? a) husband only ____; b) wife ________; c) both husband and wife _________; d) all household members ________.

3.1.6.7 Estimate the average working hours for men and women per day:

Stratum	In the house (hr)	Outside the house (hr)
Men		

Women		

3.1.6.8 Do men/husbands participate in the house tasks? a) Yes ____; b) No. ________.

3.1.6.9 If yes, specify?

Types of tasks	Please tick (√)
Cooking	
Cleaning household	
Milking cows	
Caring children	
Washing cloths	
Water fetching	
Fire wood collection	
Others	

3.1.6.10 Do women participate in the decision making of community affairs and development activities? a) Yes ________; b) No. ________.

3.1.7.11 What are the major problems affecting women more seriously than other groups of the society? (Please mention only the main three) (a)____ (b) _____

3.1.8 Social services

3.1.9 Education

3.1.9.11 Which type of education do you prefer for your children? 1. Formal education _______ 2. Non-formal education : ____3. Religious education: ___________

3.1.9.12 How far is the near by formal education institution for the household? In km. 1. First cycle, 1-4:, 2. Second cycle (1-8) 5-8, 3. High school 9-10 _4. Preparatory 11-12, 5. Higher education __.

3.1.9.13 Number of family members attending formal education. 1. Male __2. Female__ .

3.1.9.14 What are the major problems constraining education in your community? 1. Absence of the school ___ 2. Unable to cover school expenses ____3. HH demand for children labor .

3.1.10 Health

3.1.10.11 What are the most common diseases prevailing in your area?

Types of diseases	Please tick (√)
Malaria	
Diarrhea	
TB	
Intestinal parasite	
Eye disease	
STD	
Headache	
Typhoid	
Others (specify)	

3.1.10.12 Who is most affected by the local diseases? (1) children (2) youngsters (youth) (3) matured ones (4) older people (5) mothers

3.1.10.13 What are the main sources of diseases (1) water (2) infectious disease (3) malnutrition (4) STD

3.1.10.14 Which of the diseases have significant effect on agricultural labor forces? (1) Malaria (2) Diarrhea (3) HIV/AIDS (4) Typhoid (5) any other (Specify) -----------

3.1.10.15 Where do you go for treatment when one of your family members gets sick? 1. Hospital ___ 2. Hearth center ____ 3. Clinic __ 3. Health post ____ 4. Traditional healer ________ 5. Self treatment _______ 7. Stay at home _______________

3.1.10.16 If the member of your family gets treatment by traditional healers, what do you think about the source of medicine to heal the illness? 1. Plants _____ 2. Soil ___ 3. Water _________

3.1.10.17 If the medicine is obtained from plants,

Species	Type of disease	Parts of plants to be applied/ used	Collection methods	Storage system	Dosage quantity	Effectiveness

3.1.10.18 What are the major constraints in health services?

Major constraints	**Please tick (√)**
Distance	
Shortage of medicine	
Lack of health personnel	
High treatment and medicine cost	
Reluctance of the health personnel	
Lack of accessibility to reach the reach to reach the health services	

3.1.10.19 How do you get traditional medicines from traditional healers? 1. upon payment 2. Freely 3. Both

3.1.10.20 Who is more responsible for provision of traditional medicines? 1. Women; 2. Men 3. Both

3.1.10.21 How these traditional healers get their knowledge of traditional medication? 1. from their parents; 2. special training by traditional healers 3. both

3.2 Plant Inventory Form

Plot No. _____. Land use type: _______. Name of the owner: ____

Plot size: ________ ha

3.2.1 List of tree and shrub species

No.	Local name	DBH	Height	Type of plant/tree, fruit tree, shrub	uses

4. INFORMATION AT KEBELE LEVEL THROUGH GROUP DISCUSSION WITH KEBELE LEADERS AND OTHER MEMBERS.

1. Name of Kebele ________________ 2. Area _______ ha. 3. Population size______
4. Number of households living in the kebele but who are not the members of the Kebele Association_________ 5. Number of land less households _________________

6. Total animal population in the Kebele: a) cows and oxen b) sheep and goat c) equines d) chickens

7. Land use system of the Kebele and areas under different land uses in hectare:

a) Agriculture ___ b) pasture ___c) forest ___ d) house___e) out crop __f) others (specify) __

8. What are the main constraints that the farmers are asking to be solved? ((a) __(b) ______

9. What are the major problems in the livelihood improvement of the local communities and environmental protection? a) ____(b)____(c)_____(d)________

CHECKLISTS

1 What are the major land use systems in the area?
2 How do you assess the historical development of forest cover of the area? (a) Past and current situation of natural forests, and (b) Past and current situation of plantation/agroforestry development
3 Is the forest cover increasing or decreasing? (a) If increasing, natural or plantation forests, (b) If decreasing, the main causes for deforestation, and (c) Effects of deforestation
4 What are the major indigenous species growing in the areas?
4.4 Species 1. (a) Uses, (b) growing place (homegarden, on farm, pasture, forest, …), (c) Parts used (d) Conservation status (abundant, threatened,). (e) Contribution to food security (f) Contribution to income generation
5 What are the major uses of forest resources?
6 Which species are important for: (a) fuel wood (b) construction (c) household furniture (d) fodder (e) food (f) shade (g) cash income (h) medicinal (i) ornamental (j) cultural, and (k) another (specify)_________________________
6 Which of the uses needs special knowledge? And how this knowledge is acquired?
7 How many people of your community know medicinal plants?
8 Who are the main knowledgeable persons in traditional medicines, i.e. women, men, both)?
9 What are the main agricultural crops in the area?
10 The varieties of traditional crops: (a) Crop, (b) Traditional varieties, landraces (c) Conservation of these traditional varieties (d) Modern varieties and their availability
11 Which of the crops are prioritized for: (a) Household consumption (b) Cash income (c) Land productivity improvement
12 How is the productivity of agricultural lands? (a) Increasing (b) decreasing
13 If decreasing why?
14 How do you maintain or improve land productivity of the area?
15 How is the trend of using chemical fertilizers? Increasing; why? Decreasing; why?
16 How is the yield of the agricultural crops from time to time when you use the same amount of fertilizer per ha? (a) Increasing; if increasing why? (b) Decreasing; if decreasing why? By how much in the last five years? (c) The same
17 Which one do you prefer to use for agricultural productivity improvement? (a) Use of fertilizer? (b) Use of traditional methods? Please, list the inputs you use. (c) Both (for the same area; different areas)
18 Have you observed any change on your land features after you have started to use fertilizer?
19 How do you evaluate/main indicators of/ land productivity of the area?
20 How many farmers are using traditional farming systems i.e. without fertilizer, insecticide, herbicides?
21 How is the trend of using agro-industrial inputs over the last five years? Increasing? Decreasing? Why?
22 What are the main problems in the agricultural production of the area?

MARKET PLACE DATA COLLECTION

Location _________Collector _____collection Number: _______ date _____

1. INFORMATION ON THE VENDOR OF TRADITIONAL MEDICINE

1.1 Name: ________________

1.2 Type of vendor: 1. Permanent stall 2. Temporary stall 3. Irregular

1.3 Village of vendor _________ Gender: 1. male 2. Female

1.4 Estimated age______

1.5 How often they sell here? 1. Every day _ 2. Twice a week 3. Once a week __

1.6 In other markets? ___________

Type of product (use category)	Species	Unit		Quantity		Unit price	
		Local	Kg	Local	Kg	Local	Kg

2. CROP MARKETING

2.1 What are the main crops for sale?______________

2.2 Are there specific perennial cash crops you grow and sell? Yes/No; If yes, which ones are these? __________________

2.3 For which crops price are satisfactory and which ones low? _________________

2.4 Do you feel that transportation costs are reasonable? Is produce marketed individually or by group? __________________________

2.5 Do you think that the markets in your proximity can absorb additional produce? How is the accessibility? Are markets accessible throughout the year?_____________

2.6 Do you think that if your crop production increases you would have no difficulty finding new markets? What kind of outlet do you have and/or foresee? ______

2.7 Are you satisfied with the marketing infrastructure in your village or nearest market town (assembly points, market facilities, etc.) ______________

2.8 How might be your marketing situation can be improved? ___________________

INFORMATION ON THE COLLECTION

1. Local name: _______________________ 2.Life form: ______________

3. Village: _____________________ 4.vegetation type: _________________

5. Cultivation status: cultivated___ managed_____ wild________

6. Marketing status: gathered by vendor________ resold_____________

7. Number of species in collection: single mixture of __________plants

8. Name of other ingredients: ______________________________

9. Condition of plants: fresh____ dried__ preserved_____ in _______________

10. Price/unit: __11. Brought to market: daily__weekly __on occasion _______

12. Estimated quantity: vendor _______ whole market ___________

13. Availability: Jan Feb Apr May Ju Jul Aug Sep Oct Nov Dec

14. How much sold now compared to in past: more __ same__ less ___

Why? Less available for harvest less demanded by buyers other _________

15. Use: ____

16. Plant part used: ___________________________________

17. Preparation: _______________________________________

19. Notes: ____

HERBARIUM INFORMATION

Botanical family ____________ Scientific Name: _________________

Preparation: herbarium specimen sprit collection Ziploc bag

Distribution: _________________ ___________________ ___________

Total number of duplicates: ___________________________

Life form ____________

DECLARATION

I, the undersigned, declare that this thesis is my own original work, has not been presented for a degree in any university and that all sources of material used for the thesis have been duly acknowledged.

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