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Fruit tree species in the wild and in homegarden agroforestry: species composition, diversity and utilization in western Amhara region, Ethiopia

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Submitted

By

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Declaration

I, the undersigned, hereby declare to the University of Natural Resources and Applied Life Sciences, Vienna that this is original research work and all sources of materials used are accordingly acknowledged. This work has not been submitted to any other educational institutions for achieving any academic degree awards.

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Place and date: Vienna, September 2008

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Abstract

Intransigent problems of acute food insecurity, poverty and malnutrition are at their highest in Amhara region. Fruit-based agroforestry could be a suitable pathway towards improved livelihoods which could be developed from both exotic and indigenous wild fruits. However, alongside of the catastrophic deforestation, wild fruit species are becoming unfortunate victims and prone to extinction. Paradoxically, wild fruits suffer notable disregard from research and development and neither are the cultivated fruits attained the required focus and their potential exploited. This study examines fruits from the wilderness and in homegardens. Specifically, it focuses on assessing the species composition and diversity, cultural and tree management practices, state of exploitation and level of wild fruits domestication. It further appraises the cultural domain of wild fruits, local knowledge, perceptions and species priorities of people, and the underlying constraints and enabling factors of fruit production. The study took place in the Adiarkay, Debark, Dejen, Bahir Dar, Bure and Jabi Tehnan districts of Amhara region, Ethiopia between July 2006 and May 2008. Data were collected by means of structured, semi-structured and key-informant interviews, free-listing, direct observations and farm fruit tree censuses, and focus group discussions. Respectively, 150 and 90 household head informants were interviewed to gather data on wild and cultivated fruits. A year-round stock-taking of market stands was conducted to gather market information on wild fruits. Soil and fruit samples were analyzed to judge the soil fertility and nutritional value of fruits in that order. Results on wild fruits ratified that altogether 48 species are available for use in the wilderness. Most of these species occur in the low to medium altitude ranges rather than in the highlands, which is explained by the extremely harsh climate and a high degree of anthropogenic influence in the latter. Albeit primarily for non-fruit utilities, 17 species occur in the realm of anthropogenic ecosystems highlighting that some level of domestication is on the go. Sites that recorded higher species richness in the overall landscape have a better farm integration of fruit species and higher diversity. Propensity of farmers to domestication was pessimistically influenced by factors as free availability outlook, illiteracy, land shortage and farm position on a gentle slope. The wild fruits domain of the study area constitutes 46 species, *Carissa spinarum*, *Cordia africana, Ficus sycomorus* and *Ziziphus spina-christi* being species of higher salience and informant consent. Youngsters are more knowledgeable on wild fruits to elders shedding light on the perpetuation of indigenous knowledge. In homegardens, a total of 104 species were recorded of which fruits constitute only 15 species that varies by garden and site. Most sites appear closer in their species compositions and fall under one prototype suggesting the possibility of employing similar species, management strategies and recommendation domains. Trained household heads and altitude were found to favorably affect species richness of gardens whereas garden distance from marketing center and residence influence inversely. Species abundance tends to increase as garden size increases and in gardens of men-headed households and decreases as garden distance to market increases. Seed remains the major mechanism of regeneration both for cultivated and wild fruits which is bound to confer inferior yield and quality, and underpins the need for vegetative propagation. Fruit crops do not receive the necessary inputs, cultural and tree management. As a result, the quality of planting material is mediocre and its supply far from adequate. Neither do they receive strong technical support from research and extension. For the continuous enrichment with manures, most gardens recorded good soil fertility. Synthetic fertilizers are virtually absent and so are pesticides. The findings tip off that growers would have a good opportunity to fetch premium prices through marketing organic produce. Fruit growing is inextricably linked with the availability of supplemental river-based irrigation water. However, potential water sources like ground water and rain water harvesting remain less exploited. Both wild and cultivated fruits are available year-round and have a great potential to fill food and nutrition gaps at times of most need. Indeed, some wild fruit species were found well laden with important nutrients. Nonetheless, the level of fruit use is very low that a great portion of the produce is sold. People's alimentation custom, ignorance of nutritional value, need for cash and local taboos are a large part of the explanation. As a result, food value has rather a subordinate role and wild fruit bearing species are currently utilized for various utilitarian functions pertaining to social, economic and ecological services. Thus, fruit gleaning and consumption remains largely children domain. Some ten species of wild fruits and almost all cultivated fruits are sold in local markets, but trade flows, prices, and incomes appear to be very low. Seasonal gluts and lack of processing facilities contribute to the stumpy price. Value addition techniques and strategic growing of different maturity group varieties could lend a solution. Generally, fruit production is constrained by several agro-ecological, socio-economic and cultural factors. Detail analysis of plant associations in the homegardens, promotion and mainstreaming of fruits to achieve sustainable behavioral changes, wild fruits germplasm collection, improved input and planting material supply and technical backstopping are suggested. In sum, *Carissa* species, *Dovyalis abyssinica*, *Diospyros mespiliformis, Mumusops kummel, Rosa abyssinica, Syzygium guineense, Tamarindus indica, Ximenia americana* and *Z. spina-christi* among the wild fruits, and mango, guava, avocado, orange and papaya among domesticates are priority species worth further in-depth investigation and promotion for wider consumption.

Key words: agroforestry, cultural domain, diversity, domestication, homegarden, wild fruit

Zusammenfassung

Die Amhara Region ist von unlösbaren Problemen wie unsicherer Nahrungsversorgung, Armut und Unterernährung am stärksten betroffen. Agroforestry auf der Basis von Obstgehölzen könnte einen angemessenen Weg zu verbesserten Lebensbedingungen darstellen und kann sowohl mit fremden als auch mit einheimischen Wildobstarten betrieben werden. Im Zuge der katastrophalen Abholzung werden Wildobstarten allerdings zu Opfern und sind vom Aussterben bedroht. Paradoxerweise werden Wildobstarten von der Forschung und praktischen Umsetzung nur wenig beachtet; ebenso wenig sind kultivierten Früchte mit der erforderlichen Aufmerksamkeit bedacht worden um ihr Potenzial zu nutzen. Diese Studie untersucht OBstgeölze in der Wildnis und in Gärten. Der Schwerpunkt liegt in der Bestimmung und Auswertung von Artenzusammensetzung und -vielfalt, Kulturpraktiken und Baumbewirtschaftungstechniken, Erschließungszustand und Grad der Domestizierung von Wildobstarten. Weiters werden die kulturelle Domäne von Wildfrüchten, lokales Wissen, Sichtweisen und Artenprioritäten der Bevölkerung, sowie die zugrundeliegenden Einschränkungen und Faktoren, welche die Fruchtproduktion ermöglichen, abgeschätzt. Die Studie wurde in den Gebieten Adiarkay, Debark, Dejen, Bahir Dar, Bure und Jabi Tehnan, in der Amhara Region, Äthiopien, zwischen Juli 2006 und Mai 2008 durchgeführt. Die Datenerhebung erfolgte durch strukturierte und semi-strukturierte Interviews mit wichtigen Informanten, Free Listing, direkte Beobachtungen und Erhebungen über Obstbäume auf Farmen, sowie gezielte Gruppendiskussionen. 150 bzw. 90 Haushaltsvorstände wurden befragt um Daten über wilde bzw. angebaute Obstgehölzarten zu erhalten. Eine ganzjährige Lagerbestandsaufnahme an Marktständen wurde durchgeführt um Marktinformationen über Wildfrüchte zu beschaffen. Boden- und Obstproben wurden analysiert um die Bodenfruchtbarkeit und den Nährwert der Früchte in dieser Reihenfolge beurteilen zu können. Die Ergebnisse für Waldfrüchte ergaben, dass insgesamt 48 Arten für die Nutzung in den Naturwäldern verfügbar sind. Die meisten dieser Arten kommen eher in den niedrigen bis mittleren Höhenlagen vor als im Hochland, was auf das extreme Klima und einen hohen Grad an menschlichem Einfluss im letzteren zurückzuführen ist. 17 Arten kommen im Bereich der anthropogenen Ökosysteme vor, wenn diese auch in erster Linie zu anderen Zwecken als zur Fruchtnutzung kultiviert werden. Dies verdeutlicht, dass ein gewisser Grad an Domestizierung stattfindet. Auf Versuchsflächen, die einen höheren Artenreichtum in der Landschaft aufweisen, gibt es eine bessere Integration von Fruchtarten auf Farmen und größere Diversität. Die Neigung der Farmer zur Domestizierung wird negativ beeinflusst durch Faktoren wie Aussicht auf freie Verfügbarkeit, Analphabetismus, Landknappheit und die topographische Lage der Farmen. Die Wildfruchtdomäne des Untersuchungsgebiets

umfasst 46 Arten, wobei die Spezies *Carissa spinarum*, *Cordia africana, Ficus sycomorus* und *Ziziphus spina-christi* besonders hervorspringen und das Wissen der Informanten eindeutiger übereinstimmt. Jugendliche kennen sich mit Wildfrüchten besser aus als Ältere, was ein neues Licht auf die Bewahrung von indigenem Wissen wirft. In den Hausgärten wurde eine Gesamtzahl von 140 Arten erfasst, wovon Früchte nur 15 Arten ausmachen, diese wiederum variieren von Garten zu Garten bzw. von Standort zu Standort. Die meisten Standorte weisen eine relative einheitliche und geschlossene Artenzusammensetzung auf und es besteht darin eine große Ähnlichkeit zwischen den Standorten, sodass auch ähnliche, Managementstrategien und Bewirtschaftungsempfehlung genutzt werden können. Der Bildungsgrad der Haushaltsvorstände sowie Höhenlagen erwiesen sich als positive Einflüsse auf den Artenreichtum der Gärten, wobei die zunehmende Entfernung des Hausgartens zu den Märkten und Wohngebieten sich umgekehrt auswirken. Die Artenvielfalt nimmt mit wachsender Gartengröße und in Gärten von Haushalten, die von Männern geleitet werden, zu. Andererseits sinkt sie mit größerer Entfernung vom Markt. Die Vermehrung der Obstgehölze erfolgt hauptsächlich über Samen, sowohl für die Kultur- als auch für die Wildobstarten, was sich in minderwertiger Ernte und Qualität niederschlägt und die Notwendigkeit vegetativer Vermehrung untermauert. Die Fruchternte erhält nicht die notwendigen Inputs hinsichtlich Kultivierung und Baummanagement; die Qualität des Pflanzmaterials ist mittelmäßig und die Versorgung bei weitem nicht angemessen. Genauso wenig gibt es starke technische Unterstützung aus der Forschung und der Beratung. Aufgrund der kontinuierlichen Zufuhr von Dünger aus der Viehhaltung weisen die meisten Gärten eine gute Bodenfruchtbarkeit auf. Künstliche Düngemittel sind praktisch nicht vorhanden, genau wie Pestizide. Diese Fakten weisen darauf hin, dass die Bauern gute Möglichkeiten hätten erstklassige Preise durch die Vermarktung organischer Produkte zu erzielen. Der Obstanbau ist untrennbar mit der Verfügbarkeit von Flusswasser für die Bewässerung verbunden. Potenzielle Wasserzufuhr aus der Grund- oder Regenwassergewinnung bleibt allerdings ungenutzt. Sowohl wilde als auch angebaute Obstarten sind das ganze Jahr über verfügbar und haben ein großes Potenzial in Notzeiten die Ernährungslücken zu füllen. Einige Wildfruchtarten verfügen in der Tat über wichtige Nährstoffe, doch trotzdem ist der Grad der Obstnutzung sehr niedrig, sodass ein großer Anteil der Ernte verkauft wird. Die Hauptgründe dafür liegen in den Ernährungsgewohnheiten der Bevölkerung, Unwissenheit über den Nährwert der Früchte, Bargeldbedarf und lokalen Tabus. Daraus folgt, dass der Nährwert des Obsts eine untergeordnete Rolle spielt und wilde Obstgeölze zurzeit meist für verschiedene andere nützliche Zwecke angepflanzt werden, darunter soziale, andere wirtschaftliche und ökologische Funktionen. Das Einsammeln und der Verzehr von Obst bleibt daher größtenteils die Domäne von Kindern. An die zehn

Wildfruchtarten und fast alle Kulturobstarten werden auf lokalen Märkten verkauft, aber die Handelsströme, Preise und Einkommen scheinen sehr gering zu sein. Saisonale Überfülle und der Mangel an Weiterverarbeitungsanlagen tragen zu den Billigpreisen bei. Wertsteigerungstechniken und der strategische Anbau von Obstgehölzen mit verschiedenen Reifezeitpukten könnten eine Lösung darstellen. Im Allgemeinen ist die Fruchtproduktion durch verschiedene agro-ökologische, sozio-ökonomische und kulturelle Faktoren eingeschränkt. Eine detaillierte Analyse von Pflanzengemeinschaften in Gärten, sowie die Förderung und Werbung für den Fruchtkonsum um nachhaltige Verhaltensänderungen zu bewirken, die Sammlung von Vermehrungsgut für wilde Obstgeöhlze, verbesserter Input und bessere Versorgung mit Pflanzmaterial, und nicht zuletzt vermehrte technische Unterstützung werden vorgeschlagen. Zusammenfassend kann gesagt werden, dass *Carissa*-Spezies, *Dovyalis abyssinica, Diospyros mespiliformis, Mimusops kummel, Rosa abyssinica, Syzygium guineense, Tamarindus indica, Ximenia americana* und *Z. spina-christi* unter den Wildobstgehölzen und Mango, Guave, Avocado, Orange und Papaya unter den domestizierten Früchten Vorzugsarten darstellen, die einer tiefergehende Untersuchung würdig sind und deren Verzehr gefördert werden sollte.

Key words: Agroforestry, kulturelle Domäne, Domestizierung, Hausgärten, (Bio-)Diversität, Wildobsttgehölze

Table of Contents

Page

1 Introduction

"*And the LORD God planted a garden eastward in Eden… And the LORD God commanded the man, saying, of every tree of the garden thou mayest freely eat…*" (Genesis 2: 8 -16)

For millennia, ecosystems and indigenous populations have evolved in symbiosis until human societies gradually moved from dependence on wild foods to domesticated plants and animals (FAO 1995). Nevertheless, there is no progressive evolutionary trend of development from hunter-gatherer to settled agriculture and livestock keeping since in all settings and areas worldwide gathering and hunting remains an important component of the livelihoods of agricultural peoples (Scoones et al. 1992). Hence, several species including fruits are to date exploited in wild states as much as from their cultivated sources.

Fruits are undoubtedly man's oldest food dating back to Adam, Eve and the forbidden apple. Some of the fruits like date palm and pomegranate have been mentioned in records as long ago as 7,000 BC and 3,500 BC, respectively (Singh 1995). In the wilderness they have sustained people all over the world throughout history and their consumption is documented from antiquity into the Common Era (Grivetti and Ogle 2000; Redzic 2006). When man took to organized agriculture he cultivated grain crops, but also, undoubtedly he grew some fruits in his backyard. To date, fruits in their wild states provide a safety net for millions around the globe on a daily basis particularly the poor who are ill - served by the market economy.

Fruits contain almost all known vitamins and many essential minerals (Simitu 2005), yield much more produce per unit of area and are more lucrative than ordinary farm crops (Gill et al. 1998). They are thus important components of a healthy diet. If consumed daily in sufficient amounts they can help prevent several major diseases (WHO 2005) and can improve the nutrition and health of children, the elderly and immune-compromised individuals such as HIV/AIDS patients (Barany et al. 2001).

Characteristically, fruit and vegetable production easily undertaken by unskilled people can play an important part in poverty alleviation programmes and food security initiatives, providing employment opportunities and a source of income. In addition, as it is well adapted for small-scale production units, it can provide relief for people at the individual household level. It also offers opportunities for trade and earning foreign currency, which bring a comparative advantage in the context of globalization (WHO 2003).

Gathered in the wild they provide cheap food and add variety to diets, improve palatability, and provide essential vitamins, minerals, protein and calories (Arnold 1995). They also form an important component of coping strategies in times of severe famine where many lives are saved (Guinand and Dechassa 2000). Many of the wild edible fruit species have a great potential when it comes to processing**.** Used in an agroforestry system they often offer multipurpose advantages (Shrestha and Dhillion 2006) and can help in soil and water conservation (Halland 2004).

In Ethiopia, the wide range of climatic and edaphic conditions permit the growing of a variety of fruit crops all-year-round. On account of the cultural and ecological differences, intra- and inter-specific variations in the diversity of several horticultural crops and their wild relatives are also immense (IBCR 2001). Nevertheless, the principal types of fruits produced in significant volumes are few (World Bank 2004). On the other hand, the wild edible flora of the country is rich as over 200 species of wild and semi-wild plants have been used since antiquity by people in rural areas either at all times or during times of food shortage (Mesfin 1997; Getachew et al. 2005). Brought under domestication in agroforestry system and in the wilderness, most of these species can contribute to achieving food and nutritional security and promoting poverty alleviation and environmental rehabilitation (Getachew et al. 2005).

Nevertheless, cultivated and wild fruits alike have not been accorded due attention in Ethiopia and their potential remains much unexploited. As a result, fruit intake is grossly inadequate so that the country's nutrition indicators are appalling. Of the 1.3 to 37.4 kg $^{-1}$ capita $^{-1}$ year $^{-1}$ fruit consumption for sub - Saharan Africa, Ethiopia scores the lowest figure (Ruel et al. 2005). The per capita food available for consumption is also very low, where on average Ethiopians have access to only approximately 1650 kcal day $^{-1}$ capita $^{-1}$ (Getachew 1995) which is far short of the recommended 2100 kcal diet (Iannotti et al. 1998). Consequently, malnutrition, which is mainly attributed to the low intake of fruits and vegetables, is a serious public health problem in many parts of the country, especially in the Amhara region, where a cereal-based farming system remains extensive. Fruits are one of the potential candidates worth high consideration to curb the extant malnutrition and mitigate poverty.

With the prospect of contributing to the development of fruit-based agroforestry, this study documents fruit resources both from homegardens and gathered in the wilderness with respect to species diversity, state of exploitation and management, potential contribution to food and nutritional security, as well as the underlying constraints and enabling factors, in the western Amhara region of Ethiopia.

1.1 Problem statement and significance of the study

In several districts of the Amhara region, intransigent problems of acute food insecurity, poverty and malnutrition are commonplace. The low levels of agricultural productivity, land fragmentation and recurrent drought in parts of the region combine to leave nearly a quarter of the population food insecured (ADA 2003). Deforestation is at its highest in the region that left only in the order of one to three percent of the forests (USAID 2000). The land availability to the farming families has progressively declined to an average landholding per household of 0.75 ha (Nega et al. 2003) and 94 % of households have insufficient land to meet their food needs (USAID 2000). As a result, most rural people can no longer afford to put aside land separately for perennial crops like fruits. This dictates the need for increased farmland diversification to provide solutions that successfully combine increased food and nutritional security, cash generation and biodiversity conservation gains.

In this regard, agroforestry appears the best candidate to help enhance the stability and productivity of agro-ecosystems (Kindt et al. 2001) and alleviate environmental stresses (Leaky and Jaenicke 1995). Especially fruit-based agroforestry can play an important role in alleviating poverty by contributing both products and important ecological services. Besides, for the many crop components and combinations possible, this system is highly adaptable and applicable to a wide area and range of physical and social conditions (Withrow-Robinson et al. 1999 & 2005). Especially integrated agroforestry systems like homegardens are a suitable pathway toward improved livelihoods in rural smallholder systems (Garrity 2004). Hence, integration of fruit tree species in homegardens holds a substantial potential in terms of economic and ecological feasibility, as well as social acceptability, and could enormously enhance household food-security situations through improved sustainable production.

To this end, in the Amhara region modest extension efforts have been made in the past by governmental and non-governmental organizations to supply farmers with fruit and other useful plant species for growing in their homegardens. Similarly, farmers have a tradition of growing a variety of plants including fruit trees on their own. Surprisingly, however, no or very little research has so far been done on homegardens as a system and their fruit components in the region, although their multitude advantage would warrant more recognition. As a result, the potential contribution of fruits and homegardens in general to peoples´ welfare remains largely unrealized.

In efforts to buttressing long-standing local practices of tree domestication by farmers, a recent shift has been made in different parts of the world towards integrating indigenous tree species with a potential to generate cash for farmers into farming systems. One important component of this approach is the domestication of indigenous fruit tree species of commercial potential (Leaky and Simons 1997) which is, for instance, on the move in several parts of Africa (Leakey et al. 2003; Teklehaimanot 2004b; Shackleton and Shackleton 2005). This approach could as well be emulated in the Amhara region and fruit - based agroforestry can potentially be developed from indigenous fruits as much as from exotic fruit sources.

Given that they are adapted to the local environment, wild fruits can grow easily with few requirements for external input and be integrated into sustainable farming systems.

Currently, alongside of the catastrophic forest destruction, wild fruit species are likely to be unfortunate victims and prone to extinction. Thus, apart sustainable use in the wild, evolving them into agroforestry trees through a process of domestication would be a viable approach to realizing their potential (Simitu 2005) thereby conserving and setting in motion the advancement toward food security. Paradoxically, promising as they might be, however, research and development initiatives in the region largely disregard wild fruit species, and studies specifically dedicated to indigenous fruit trees are generally few, even in the country (Demel and Abeje 2004). Research concerning the socio-economic, cultural, traditional, nutritional and conservation aspects of wild-food plants still lacks adequate attention and little, if anything, has been systematically documented in much of Ethiopia in general (Guinand and Dechassa 2000; Halland 2004; Getachew et al. 2005) and in the Amhara region in particular. Likewise, information on wild edible fruits and edible plant species in general is extremely scarce in the Amhara region.

This study is expected to contribute toward bridging the existing information gap with respect to the type and diversity of fruit resources available and its extant use and management, farmers' local ecological knowledge and perceptions, as well as potential contribution to food and nutritional security and the underlying constraints. The findings would find practical application by being utilized as an input for research and development institutions and policy makers in their planning relevant interventions.

1.2 Objectives

1 To determine the species composition and diversity of fruits in the wilderness and in homegarden agroforestry. Relevant questions to be answered include: What are the species compositions and diversity of wild edible fruits in the overall and agricultural landscape and how does this compare across sites, niches and agro-ecologies? What is the level of wild fruits domestication? What are the species compositions and diversity of cultivated fruits and other species in the homegardens and how does this compare across households and sites? How is the existing traditional homegarden fruit tree-based production system described? How are plant associations, and vertical and spatial configuration of species in the homegardens? What degree of intra-specific variability exists? How is the tree population trend? What are the factors influencing fruits species diversity under the wild and cultivated conditions and propensity of farmers on wild fruits domestication?

2 To assess the degree of cultural practices, tree management regimes and support services in fruit growing. It specifically tries to answer questions related to: What practices are underway with respect to cultivation, nursery management and propagation, fertility maintenance, pest and disease control, watering, etc.? How are the trees managed? How much focus and technical backstopping does fruit growing receive? What are the underlying constraints?

3 To appraise the level of fruit availability, exploitation and income generation activities. Under this sub-objective we question: How is the fruiting phenology? To what extent and how are fruits used? How important are fruits in peoples' livelihoods? How much nutrients do fruits provide? How are fruit transactions and prices? What other non-fruit utilities are made of wild fruit bearing species? What factors hinder the exploitation of fruits?

4 To elicit and obtain a better understanding of the local knowledge, perceptions and fruit species priorities of people. This sub-objective revolves around: What is the cultural domain of wild fruits? How much do people know about fruits and their environment? How does the knowledge of people on wild fruits vary and what factors influence it? What are the insights of local people into fruits, especially wild fruits, and their attitudes towards domestication? Which fruit species are valued most and why?

2 Literature Review

2.1 Wild edible fruit bearing plant species

2.1.1 The concept "Wild"

The term "*wild*" when applied to plants or plant species it refers to those that grow spontaneously in self-maintaining populations in natural or semi-natural ecosystems and can exist independently of direct human action (FAO 1999). This implies that the degree of human intervention involved determines a species to be regarded wild or domesticated where the later have to rely on human management for their continued existence. However, because of wild-domesticated species continuum resulting from co-evolutionary relationships between humans and their environment it is practically difficult to make a distinction between "wild" and "domesticated" dichotomy (FAO 1995 & 1999; Bell 1995). In the context of the present study, therefore, "*wild edible fruits*" is used to stand for those edible fruit bearing plant species dwelling in the agricultural landscape-natural milieu continuum and thus not recognized by the community exclusively as domesticates.

2.1.2 The role of wild fruits in food and nutritional security, and livelihoods

The uses of wild foods, in which wild fruits form a part, as a diet supplement at times of plenty and component of local response to increasing food insecurity, and as one of the major coping mechanisms at times of food shortage and famine is widely documented (Abbink 1993; Bell 1995; Edwards 1992; Guinand and Dechassa 2000; Mojeremane and Tshwenyane 2004; Getachew et al. 2005; Redzic 2006). They play an important role to tide communities over the hunger season that precedes the harvest and to provide people with the necessary energy to harvest their fields (Bell 1995). For instance, while the Yanomami Indians in Venezuela regularly use about 20 wild plant species, they add another 20 species when food is in short supply that are often ignored at normal times (FAO 1999). In Botswana, in poor rainfall years when arable agriculture fails indigenous fruit trees bridge the gap and improve food security for rural households (Mojeremane and Tshwenyane 2004). In Zimbabwe, it was found out that, among other factors, the degree to which indigenous fruits are used/are available for income smoothing determines vulnerability to poverty (Mithöfer and Waibel 2004). Similarly, collection and consumption of wild plants as well as the domestication of a great variety of indigenous plants and trees for home consumption and medicinal use has enabled Ethiopian populations to survive in a region beset by periodic food shortages. For instance, during food shortages and impending famine, the Meén people of south-western Ethiopia gather quite a large number of wild edible plants including fruits like *Ficus* and *Carissa* species by migrating into the lowlands (Abbink 1993).

Foods from wild sources do also serve a "buffer food" and play a very crucial role of rescuing lives of people at times of famine. For instance, wild foods had a critical role in major famines like the 1973 and 1984-5 of Sudan (Bell 1995), the 1965/66 of Bihar in India and 1974/75 of Bangladesh (FAO 1999). For many rural Ethiopians, memories of reliance upon wild food plants for survival during famine periods as they call it "*Kifu Qen*" to mean wicked days are commonplace. During drought stricken years of 1966-69 where repeated significant harvest losses and complete crop failures were incurred, the Konso people of Southern Ethiopia managed to cope and survive by increasing the consumption of wild food plants (Guinand and Dechassa 2000). Kebu and Fasil (2006) recorded 27.3% of the 66 wild edible plants in Derashe and Kucha districts in southern Ethiopia consumed only during famine or in times of food shortage. However, the use of wild foods during times of crisis is not a historical anecdote or aberration, but a present day reality for people across the globe as reports from Bosnia-Herzegovina, Congo, Burma, North Korea, Colombia and a host of other countries make clear (Pierce and Emery 2005; Redzic 2006) and in exceptional cases may be the only source of food available (FAO 1999). Apart from avoiding hunger, households harvesting wild fruits can boost rural employment and generate income, through processing and value adding (Akinnifesi et al. 2005). In addition to fruit production and cash, wild fruits offer several other benefits: firewood, fodder, building material, shade and medicine to rural communities (Mojeremane and Tshwenyane 2004).

Wild foods also contribute to diet diversity and flavor thereby constitute an essential part of an otherwise bland and nutritionally poor diet (Bell 1995; FAO 2005) while they serve dietary replacement for populations that in their daily diet consume unhealthy food (Redzic 2006). The use of plants belonging to the wild flora is common today as a supplement for healthy diet even in the well-off regions of the world like in Canada (Murray et al. 2005), Turkey (Dogan et al. 2004) and Bosnia-Herzegovina (Redzic 2006). Many of these wild edibles are reported to have as high as or higher amounts of vitamins and other important nutrients than domesticated species. For instance, while the vitamin C content of an orange is famously high at 57 mg/100 g, the fruit of the baobab tree has 360 mg/100 g and *Ziziphus jujube* var. spinosa 1000 mg/100 g (FAO 1992). Ruffo et al. (2002) reported high protein and fat contents in *Adansonia digitata* and *Annona senegalensis* and a higher vitamin C content than mango or orange in *A. digitata* and *Ximenia caffara* in Tanzania. Wild fruits and berries were also reported to add crucial vitamins to the normally vitamin deficient Ethiopian cereal diet, particularly for children (FAO 2005). Information is, however, limited on nutrient composition of wild edible plants in diverse agro-ecologies in Ethiopia (Getachew et al. 2005).

2.1.3 Wild edible fruit species diversity and associated local knowledge

Of 250,000 to 300,000 higher plant species known to man, only a few hundred species have been fully domesticated and many thousands are still gathered from the wild. Only 103 species of food plants contribute 90% of national per caput supplies while 20 to 30 of these species are regarded as the staples (FAO 1999). Each major geographical and agro-ecological region is bestowed with a wide range of wild edible fruit species, some of which though quite important locally, are seldom known outside that region (Nair and Merry 1995). A growing literature highlights the inventory of wild edible fruit bearing species from different parts of the world, the species richness of which vary from place to place depending on the climate, vegetation composition background, level of human intervention, scale of sampling, and similar factors. For example, on the Asian continent, inventory of wild fruits were reported from India (Thakur and Chauhan 2005; Sundriya et al. 2004), Nepal (Shrestha and Dhillion 2003), Pakistan (Khan et al. 2003), etc. In Latin America, a good account of several indigenous fruit trees was reported from Peru (Vasquez and Gentry 1989), Ecuador (Van den Eynden et al. 2003), Argentina (Ladio and Lozada 2000), etc. In Africa as well, a wider body of literature documents the diversity of wild food plants in general and wild fruits in particular. More than 800 species of edible wild plants have been catalogued across the Sahel (FAO 2005). About 800 of Kenya's total flora of 7000 species of vascular plants was reported to be used in some way as food in the wild of which 50% are fruits (FAO 1999). Similarly, about 700 indigenous fruits in Tanzania (Maduka 2004), and 150 species in Eastern Madagascar (Styger et. al 1999) have been documented.

In Ethiopia, the number of wild edible plant species is enormous. Several studies recorded the occurrence of wild edibles at different spots of the country though this information is found scattered in botanical monographs, glossaries, and informal notes as well as in the rich oral tradition of the different communities (Zemede and Mesfin 2001). However, studies specifically dedicated to wild edible fruit species are hardly found. Rather, documentations of wild fruits most often appear collated with other edible life forms under the general tenure of wild edible plants. So far, only two more or less comprehensive documentations of wild edible plants are available for country reference. One is that of Azene et al. (1993) who documented 199 useful tree and shrub species out of which 123 species regarded usable for food and medicines. Another important nation wide documentation of wild edibles comes from the work of Zemede and Mesfin (2001). The later documented 203 wild flowering plant species consumed nationwide of which edible fruit bearing species constituting 61.6%. Besides, from about 370 indigenous food plant species reported drawing from various studies by Demel and Abeje (2004), 182 species belonging to 40 families are indicated to be edible fruit or seed bearing plants. Several other wild edible recordings are rather sporadic or are area specific and mainly ponder on western or southwestern parts of the country. Abbink (1993) catalogued 21 species of wild edible plants used by the Meén people of southwestern Ethiopia. Out of 80 wild foods recorded by Guinand and Dechassa (2000) to be consumed in southern part of the country, 38 species are fruits. In Eastern Gojjam zone of Amhara region, Fentahun et al. (2005) filed more than 40 species of wild food plants. In four districts (Alamata, Yilmana - Densa, Cheha and Goma), Getachew et al. (2005) recorded 130 wild plant species, 68 (44.2%) of which contributed by fruits. Likewise, around the Dheera town in the Arsi zone of Oromia region, Tigist et al. (2006) documented 41 wild edible plant species while Kebu and Fassil (2006) registered 66 wild edible plants in Derashe and Kucha Districts of Southern Ethiopia, of which fruits are one of the most used parts. Generally, the review highlights that in most documentations the proportion of fruit species or fruit portion edible species tend to have greater proportion.

2.1.3.1 Factors influencing the species diversity of wild edible fruit species

Studies on factors influencing specifically the species diversity of wild fruits are infrequent. Nevertheless, at general plant species diversity level, literature strongly suggest that the pattern of species richness, or of some component of richness, within terrestrial plant communities at local scales is influenced by the environmental factors (Le Brocque and Buckney 2003; Zhao et al. 2005; Wang et al. 2003). The complex interaction of different environmental factors in relation to altitude leads to variation of habitat types and different plant communities and vegetation belts. Along an altitudinal gradient in south-west Saudi Arabia Hegazy et al. (1998) found out that intermediate altitudes (500 -2500 m) attain the highest species richness and diversity with relatively high evenness. Species richness and diversity was generally suggested to lower in communities characterized by environmental extremes than in mesic environments at low-to-middle elevations while evenness was greatest at higher elevations (Brockway 1998). Similarly, Wang et al. (2003) and Zaho et al. (2005) in China found the rule of the "*mid-altitude bulge*", where species diversity and richness peaks at the intermediate portion of the elevation gradient. On the other hand, in coastal lowland vegetation of eastern Saudi Arabia, the nature of soil surface and salinity were found the main factors affecting the species richness (Shaltout et al. 1997) while soil texture, organic matter, salinity and calcium carbonate were reported in Farasan Islands of Red Sea in the same country (El-Demerdash 1996). Le Brocque and Buckney (2003) opined that also historical factors such as fire or climatic/environmental conditions at time of germination or seedling establishment may be important in determining patterns in tree species richness at the local scale. From the review, it can be deduced that elevation, climate, soil and anthropological factors are responsible for a species diversity variations in local situations.

2.1.3.2 Local knowledge of wild edible plant species

Local knowledge, known variously as folk or traditional knowledge, is people's main form of knowledge that for most of human history has been adapted to the local environment and based on experience and empirical testing (Reyes-garcı´a et al. 2005). This innumerable wealth of knowledge that creates the rich and complex production systems also affords people the adaptability and resourcefulness that is so critical at times of stress, such as drought or crop failure (Bell 1995). As a result, local people’s knowledge has been a key element in several ethnobotanical studies to explore various aspects. For instance, ethnobotanical inventories of local knowledge of plants and their environment have a great value in identifying species for domestication and commercialization (Melnyk 1998; Shrestha and Dhillion 2006). For instance, Okafor (1999) has successfully used local people's knowledge for the conservation and evaluation of the use of Non-Wood forest products in Southeastern Nigeria. Nevertheless, knowledge and access to knowledge are not spread evenly throughout a community or between communities as people may have different objectives, interests, perceptions, beliefs and access to information and resources. Knowledge is generated and transmitted through interactions within specific social and agro-ecological contexts and is linked to access and control over power. For instance, differences in social status can affect perceptions, access to knowledge and crucially the importance and credibility attached to what someone knows (Warburton and Martin 1999).

Generally, ethnobiological knowledge and practice within any culture vary by geographical origin, residence, ethnicity, religion, occupation, educational background, social status and relations, income class, age and gender (Pfeiffer and Butz 2005; Martin 1995). In Tsimane’ of the Bolivian Amazon, Reyes-garcı´a et al. (2005) found schooling to positively correlate with agreement in knowledge of plant uses. Furthermore, distance from a market town correlated with higher knowledge, though agreement in uses of plants declined after about 50 km.

Knowledge differences were also reported between gender and age groups which was explained by varying responsibilities in a household (Styger et al. 1999). Shrestha and Dhillion (2006) found a greater knowledge about food plants in women than men where elder women were the most knowledgeable compared to young men in describing wild edible plants use. In a hunter-gatherer community of Borneo, Indonesia Koizumi (2005) found knowledge differences on classification of plants not only between men and women or the young and adults but also among adult men. Likewise, in the East Gojjam zone of Amhara region, knowledge variations were noted between children and adults where children recollected longer lists of species than adults (Fentahun et al. 2005). Other factors like frequency of food shortages in a specific area and or peoples way of life (Guinand and Dechassa 2000) and morphology/ phenology of plant species and familiarity with the forest terrain (Shrestha and Dhillion 2006) were also accounted for knowledge variations.

However, in many parts of the world indigenous knowledge is being lost at an accelerated pace and disappears with changes in lifestyle, that is decrease subsistence use of wild species, changing occupational patterns of household members and disappearance of village elders (FAO 1995). Especially market economy may contribute to the loss of folk knowledge of plant uses as markets allow access to substitutes for products made from plants (Locay 1989). For this reason, Getachew et al. (2005) alerted that for increased destruction of natural habitats in Ethiopia, the disappearance of wild plants would result in the loss of indigenous knowledge with their use.

2.1.4 Agroforestry potential of edible fruit bearing plant species

Agroforestry trees can supply farm households with a wide range of products for domestic use or sale, including food, medicine, livestock feed, and timber, and environmental and social services, such as soil fertility, moisture conservation and boundary markers (Franzel et al. 2001). In recent times, there is a move away from domesticating only fast-growing, nitrogen-fixing trees towards wild indigenous trees with the potential to generate cash for farmers (Leaky and Simons 1997) and further to indigenous fruits which provide better returns to farmers because of their low weight-to-value ratio which makes them also easy to transport. Interest in such species has developed particularly rapidly in dry land Africa, with increasing awareness of the value of adaptation to the capriciousness of the prevailing climates, reflected in innate resilience often lacking in exotic alternatives (Teklehaimanot 2004b). This is even more logical, as suggested by Garrity (2004), as few tree crops like coffee that have been mainstays of the economies of a number of African countries their present and prospective profitability for smallholders is reduced because of global over production. The importance of agroforestry as a land-use system is receiving wider recognition not only in terms of agricultural sustainability but also in issues related to climate change like through carbon sequestration. Hence, with adequate management of trees (including fruit trees) in cultivated lands and pastures, a significant fraction of the atmospheric carbon could be captured and stored in plant biomass and in soils (Nair 1998; Albrecht and Kandji 2003) while indirectly it helps decrease pressure on natural forests, which are the largest sink of terrestrial carbon (Albrecht and Kandji 2003; Montagnini and Nair 2004). Also, the use of agroforestry technologies for soil conservation could enhance carbon storage in trees and soils (Montagnini and Nair 2004).

Therefore, domestication of indigenous fruits is part of a strategy to improve human nutrition in rural areas and to put money into farmers' pockets in order to improve their living conditions (Jaenicke et al. 2000). For this reason, at present several indigenous fruit species are being domesticated from natural forests in several countries. For instance, the African plum, *(Dacryodes edulis* (G. Don) HJ Lam*)* and *Irvingia gabonensis* (Aubrey-Lecomte ex O. Rorke) Baill. in several African countries, *Uapaca kirkiana* Müll. Arg. in southern Africa and *Bactris gasipaes* Kunth. in Central and South America (Jaenicke et al. 2000). In West Africa, *Z. spina-christi* L. was reported to be intercropped with millet. Similarly, trees such as *Parkia biglobosa* (Jacq.) R. Br. ex G. Don f. and *Vitellaria paradoxa* C. F. Gaertn. appear the dominant indigenous tree species of agroforestry parklands in several parts of Africa (Teklehaimanot 2004b) while *Azanza garckeana* (F. Hoffm.) Exell & Hillc. is semi-domesticated in Botswana (Mojeremane and Tshwenyane 2004).

In Ethiopia too, where forests and bush lands are cleared for cultivation, farmers preserve some of the more important indigenous species by either domesticating them on their farms, homegardens or by preserving and managing them *in situ* (Guinand and Dechassa 2000). Although the intent is for non-fruit purposes, one of the best examples of agroforestry with edible fruit bearing species in Ethiopia is intercropping of *C. africana* L. with annual and perennial crops as coffee mainly for shade or other services (Badege and Abdu 2003). In this regard, Kindeya (2004) suggested promotion of native tree species like *Balanites aegyptiaca* (L.) Del. and *Z. spina-christi* as dispersed trees in croplands for agroforestry in Ethiopia that could then be exploited for both fruit and other services. Several studies show that incorporation of fruit bearing species in agroforestry is beneficial. For instance, by accumulating a higher concentration of available phosphorus and total nitrogen *Ziziphus* species improve soil quality and yield of associated shrubs and annual crops (Verinumbe 1993; Patel et al. 2003).

Quite a number of studies feature on the determinants of domestication of wild edible fruit bearing plant species and trees in general. Generally, several economic, social/cultural and environmental conditions must be satisfied before rural people will plant trees (FAO 1985). According to Akkanafasi et al. (2005) and Johnson (2002), for the lack of knowledge in propagation techniques, seedling production and tree husbandry skills, long duration to grow from seeds to adult plants uncertain markets and low prices, skills and free availability from the forests, few farmers plant indigenous fruits trees. Also reported were decline in access to off-farm tree resources, agro-ecological characteristics and land use practices, land and tree tenure and control, agrarian transformation and growth in market transactions, factor availability and allocation, and management of risk (Arnold and Dewees 1998).

Looking closely at specific demographic and socio-economic variables that influence farmers' willingness to plant indigenous fruit trees, gender, education, farm size and tenure & occupation/income were widely implied. By and large, it was suggested that female-headed households would have fewer fruit trees than male-headed households. Older farmers may have a stronger interest in tree-planting because of their longer experience and history of experimentation with different species (Degrande et al. 2006). In Mali, Thangataa and Alavalapatib (2003) found that age of the farmer, extension contact and the number of people who contribute to farm work to be important variables in determining the adoption of agroforestry. Besides, as trees are a long term investment on the farm, the propensity to cultivate them is particularly sensitive to land tenure and or use right, about which several studies have reported (Caveness and Kurtz 1993; Arnold and Dewees 1998; Place and Otsuka 2002; Bannister and Nair 2003; Degrande et al. 2006). In Haiti, it was found out that farmers install tree hedgerows on fields of less secure tenure, of lesser fertility and steeper slope, while on closer, more fertile fields of greater tenure security, tree seedlings and fruit trees were more common and there was a greater density of mature trees. In addition, older farmers manage a greater density of trees, especially when the land was in secure tenure status (Bannister and Nair 2003). Similarly, Degrande et al. (2006) in their study in Cameron and Nigeria found out that tenure and farm size as key factors affecting indigenous fruits operating at household level where they recorded the lowest number of fruit tree species in the community where 51% of farmers' fields were rented.

Neupane et al. (2002) in Nepal reported that male membership in a local NGO, female education level, livestock population, and farmer's positive perception towards agroforestry had significantly positive effects. Drawing from his work with Karen communities in Thailand Johnson (2002) suggested that the trade-offs and feasibility involved in adoption of wild edible plants in homegardens also has limitations. For example, forest species required ample shade and cooler temperatures also are not suitable for garden transplantation while other species common to riverbanks or rice paddies require more moisture than garden conditions.

On the other hand, only scanty literatures are available documenting driving forces for farmers' decisions to retain and plant different numbers and densities of wild edible fruit trees. According to Edwards and Schreckenberg (1997), these can broadly be divided into factors internal to the household (such as farm size, land tenure, access to labour and capital, and education and ethnic background of household decision makers) and factors external to the household (such as prevailing land-use system, relative availability of off-farm resources, market access and the policy and legislative context). In their investigation on determinants of fruit tree growing in Nigeria, Degrande et al. (2006) found out that the key factors determining the differences in tree-growing strategies between communities are market access, land use and access to forest resources. While within communities, it was attributed to tenure and farm size where smaller farms had higher fruit tree densities, a relationship that was particularly strong in communities with good market access.

2.1.5 Wild fruit utilization and commercialization

2.1.5.1 Fruits utilization

The selection of food has social, political and economic dimensions. Hence, production and consumption patterns of indigenous fruits reflect farmers' evaluation of the fruits in the form they are currently available where several factors play a part in such an evaluation; individual tastes and preferences being key factors (Minae et al. 1994). Generally, factors such as age, gender and season were reported to influence the use of wild fruits. For example, wild plants in Ethiopia were reported to be more consumed by young rural males than older ones in times of peace, and more are consumed by all ages and both sexes in periods of famine, wars and at the height of the dry season (Amare 1974; Guinand and Dechassa 2000). This was corroborated by a recent study of Getachew et al. (2005) who found out that the utilization of wild edible plants varies with age, sex, season or food availability where children consume relatively higher quantities.

Constraints such as repeated climatic shocks hampering agricultural production and leading to food shortages do intensify the consumption of wild-food plants as one of the important local survival strategies. In addition, seasonality is regarded an important constraint for foraging of wild fruits as the peak collection of forest fruit does not occur during the main fruiting season, but rather when they are most needed, i.e. when cultivated food supplies dwindle and the requirements for agricultural labour are limited (FAO 1995). Also, utilization of indigenous fruits depends on existing local knowledge and the economic pursuit of the people. For example, it was reported that in the *Dega* zone of Wollo in Ethiopia very poor and medium poor households get from none to 10% of their food from wild products while the better off collect from none to only 5 % (FAO 2005). In Uganda, Tabuti, et al. (2004) reported that availability of a wide variety of introduced cultivated foods and the increasing difficulty of finding in the wild and erosion of traditional knowledge about wild food plants as well as prejudices contribute to the declining use of wild fruits.

Individual decisions regarding food acquisition and consumption are also guided by local cultural perceptions, attitudes and beliefs. For instance, Guinand and Dechassa (2000) opined that strong traditions, beliefs and religious taboos obstruct people's psychological and mental willingness to use wild-plants. These authors argue that where these factors are less stringent in southern Ethiopia, people use better number of wild foods than in other regions. However, traditions are continuously changing according to new perceived opportunities and this evolution is accelerated by changes in attitude in the younger generations and immigration of people with different values. Generally, the importance of wild plants as food is believed to have gradually diminished with the advent of cultivation and modernization (Zemede and Mesfin 2001).

Once people opt to consume wild fruits, species choice can also vary among different areas or communities because of species distribution, indigenous knowledge and economic pursuits of the community (Pauline and Linus 2004). Styger et al. (1999) attributed farmers' wild fruit species preference differences in Eastern Madagascar to the duration of settlement in proximity to primary forests that resulted in differences in indigenous knowledge on individual plants and its utilization. In Zimbabwe, the degree of preference of species was found to be subjected to age and sex where older women showed the greatest interest in wild fruits (Packham 1993).

2.1.5.2 Commercialization

Marketing and processing components form the pillar of any successful local resource-based enterprise (Simitu 2005) and market demands provide significant incentives for farmers to grow trees (Pswarayi-Riddihough and Jones 1995). Hence, in an initiative seeking to integrate wild fruit tree species into the farming system through agroforestry, the system should provide marketable products that will generate cash for farmers' pockets. For instance, where commercial exploitation of indigenous fruits occur like in western and central African region, indigenous fruits show great potential as much as the exotic fruits in providing food security, vitamins and income generation (Simitu 2005).

In Ethiopia, some wild fruit species are reported to be traded on markets in different regions. *A. digitata, B. aegyptiaca, B. aethiopum*, *Carisa* spp., *C. africana*, *D. abyssinica, D. mespeliformis, Ficus* spp., *M. kummel*, *O. ficus-indica, R. abyssinica, S. guineense*, *T. indica, X. americana* and *Z. spina-christi* are commonly sold in several open markets (Guinand and Dechassa 2000; IBCR 2001; Demel and Abeje 2004; Halland 2004; Kebu and Fassil 2006).

A number ofl reasons have been accounted for the lack or less level of commercialization of indigenous fruits in several places. According to Pswarayi-Riddihough and Jones (1995), the response from farmers to market demand is influenced by how returns compare with other income-generating activities, farmers' productive capacity and available primary inputs. Other factors accounting for less level of marketing include: accessibility, lack of preservation, low level of production and low prices (ICRAF 1992; Styger et al. 1999; Okullo 2005; Minae et al. 1994). Leaky et al. (2003) found a positive correlation between fruit traits like mass and length of *D. edulis* and price per fruit in retail markets. Seasonality might also be another factor. This can be either due in part to the seasonal availability of fruits but can also be due to an acute need for cash and/or the availability of labour during slack agricultural work as they can provide a cash buffer in times of emergency or hardship (FAO 1995). Or many products do not enter commercial markets as they are consumed locally. Some products are exchanged for goods in a non-monetary fashion and small quantities are traded by several individuals (Nair and Merry 1995). Similarly, in Southern Ethiopia, wild-food plants are mostly used for home consumption and if traded on the market, they are most likely not traded for money but exchanged for other goods and foodstuff. In this respect, *O. ficus-indica* is one of the traded and exchanged wild fruits in Ethiopia (Guinand and Dechassa 2000).

2.2 Fruits in homegarden agroforestry

2.2.1 Definition and concept of homegardens

Homegardens have been variously named in English language as agroforestry homegardens, backyard gardens, village forest gardens, dooryard gardens, house gardens, mixed, kitchen, farmyard, roof top garden, household or homestead farms, compound farms or gardens (Talukder et al. 2001; Kumar and Nair 2004). However, some local names as Shamba and Chagga in East Africa are also very popular names worldwide as they represent well their systems. In Ethiopia, a very common Amharic vernacular name equivalent for the term homegarden is "*Yeguaro-ersha*" (Zemede 2001) or a closer alternative might be "*Yeguaro Meret"* meaning a land at the backyard of a house. Despite the differences in meanings, however, the concept is understood well very widely. It generally refers to the deliberate management of multipurpose trees and shrubs (the woody component) grown in intimate association with herbaceous species (mainly annual, perennial, and seasonal agricultural crops) and invariably livestock within the compounds of individual houses the whole crop-tree-animal unit being intensively managed by family labor (Fernandes and Nair 1986; Kumar and Nair 2004). Known by different names in various places, these agroforestry systems are common in all ecological regions of the tropics and subtropics, especially in humid lowlands with high population density (Fernandes and Nair 1986) though the most widely studied are those in Nigeria, Java of Indonesia and the Chagga home gardens of Tanzania.

One of the distinguishing features of most homegardens is their small size that was reported variously in different parts of the world. For instance, having analyzed ten selected homegarden systems from different ecological and geographical regions, Fernandes and Nair (1986), reported that the average size of the homegarden units is less than 0.5 ha. Other authors reported, to mention a few, from about 0.01 to greater than 0.2 ha in Ethiopia (Zemede 2001), 0.009 to 0.25 ha in Guatemala (Leiva et al. 2002) and 0.32 ha in Nicaragua (Méndez et al. 2001). Also, 0.2-1.0 ha in Venezuela (Quiroz et al. 2001), 0.16-0.59 ha in Ghana (Bennett-Lartey 2001), 0.09 ha in Cuba (Wezel and Bender 2003), 0.024-0.24 ha in Indonesia (Kehlenbeck and Maass 2004) and 0.30 ha in India (Das and Das 2005). Although homegarden allocation might be related to various factors, several reports show that it is strongly linked to the size of total landholding. For instance, in Bangladesh, homegarden size was reported to positively correlate with farm size (Ahmed and Rahman 2004).

2.2.2 Historical account of homegardening

The homegardens currently found in many parts of the world must be seen in the light of the evolution of land use by people. Homegardening has a long tradition in many tropical countries and is presumably the oldest land use activity next only to shifting cultivation (Kumar and Nair 2004; Marsh 1998). It is likely that following a long period of hunting and gathering, the emergence of shifting cultivation has been coupled to the planting of fruit and other useful trees in the fields during fallowing. Evidence of their existence dates back to 3,000 BC and possibly 7,000 BC (Soemarwoto 1987). Soleri and Cleveland (1989) specifically mention the Neolithic time. The subsequent sedentarization of agriculture has led to the creation of more or less permanent gardens with a mixed composition of tree and annual species (Hoogerbrugge and Fresco 1993). Generally, they have evolved through generations of gradual intensification of cropping in response to increasing human pressure and the corresponding shortage of arable land and capital (Nair 1993; Kumar and Nair 2004), bio-physical and agro-climatic regimes, growing conditions, and the management practices (Zemede 2001). Also, physical limitations such as remoteness of the area that force the inhabitants to produce most of their basic needs by themselves, and lack of adequate market outlets compel the farmers to produce some portions of everything they need (Nair 1993). In general, these systems have probably evolved over centuries of cultural and biological transformations and they represent the accrued wisdom and insights of farmers who have interacted with environment, without access to exogenous inputs, capital or scientific skills (Lok 2001; Kumar and Nair 2004).

2.2.3 Homegardening and fruit production in Ethiopia

2.2.3.1 Homegardening

The planting of trees around compounds (homegardening) is the most commonly practiced technology in Ethiopia (Zerihun 1999). However, there is no direct evidence as to when people began the practice of homegardening in Ethiopia. Rather according to Zemede (2001) a long history is postulated based on the antiquity of agriculture, crop composition, oral literature and rich vernacular designations in different local languages. Patches of wild *Ensete ventricosum* observed in some parts of western Ethiopia have been interpreted by some as possible relics/descendants of homegarden plants of ancient settlements abandoned long ago. Based on such evidences the beginning of homegardening is believed to have been linked with the beginning of agriculture in the country dating back 5,000 - 7,000 years (Ehret 1979). They came into existence under different modes of initiation, influenced by biotic, abiotic, socio-economic and cultural factors (Zemede 2001) and are widely distributed throughout the country and are home to a range of taxa of cultivated perennial and annual crop species and varieties.

Despite homegardening is an age old practice, however, studies on Ethiopian homegardens are rather scarce. Following a homegarden agro-ecosystem study by Westphal (1975), Okigbo (1990) described Sidamo homegardens in southern Ethiopia. Following this, a survey of Ethiopian homegardens across various geographical and ecological areas was undertaken in the early 1990s (Zemede 2001). Tesfaye (2005) suggested that Ethiopian homegardens could in general terms be categorized into two types; perennial-crop based farming systems of the south and southwest, and the cereal-crop based farming system where cereals are grown in outer farm fields while supplementary vegetables, fruits and spices are grown in the homesteads. The latter is perhaps a dominant system in most parts of the Amhara region.

Nevertheless, despite historical evidences suggesting that gardening is much older in northern than in southern Ethiopia (Pankhurst 1993 cited by Zemede and Ayele 1995), perhaps driven by high population density gardening is well developed in the later. Hence, homegardens are more famous in south and is a long-established tradition there while the northern part is known for cereal-based crop production with the plough and cereal culture that evolved during the long history of agricultural production in the country (Westphal 1975). As a result, most of the homegarden studies in Ethiopia concentrated in southern and in a few cases in central, eastern and western part of the country while the northern part remains largely unexplored. For instance, studies by Zemede and Ayele (1995); Zemede (1997); Zemede and Zerihun (1997); Tesfaye (2005); Belachew et al. (2003) all are in the above mentioned localities.

2.2.3.2 Fruit production

The most early account of observations on fruits grown in Ethiopia is that by the Portuguese monk, Father Francisco Alvares who came to Ethiopia as part of the first official delegation from a European state in 1520 (Edwards 1992). Alvares noted the growing of fruit crops like oranges, lemons, citrons, peaches, pears and figs in monastery gardens in northern Ethiopia (Westphal 1975). Grapes (*Vitis vinifera*) were already introduced to the Gondar region of Ethiopia in the 16th century (Halland 2004). Also, fruit crops such as papaya and mango were introduced long ago and the established orchards are scattered all over the country (IBCR 2001).

Nevertheless, commercial fruit production is relatively new to the Ethiopian agricultural system, dating back to only about six decades. Some fruit species are till date found only in the homegardens of descendants of the Royal family. Most of the important fruits that are produced in gardens and commercial farms are recent introductions into the country. There were only few private orchards before land nationalization in the 1970´s that were later given to farmers and state farms. However, in the last three decades, tremendous changes were observed in the production, marketing and consumption of fruits in the country (Seifu 2003).

Fruit production is not well developed in Amhara region either. Except coffee, some spices and vegetables, the cultivation and use of horticultural crops are of recent origin. Like that of the country, fruit tree cultivation in the region probably originated with the arrival of Europeans mainly missionaries who brought the species they used to grow along. They were thus grown in their homegardens and the production did not develop to a large scale to cater to the large segment of the population to fully appreciate the nutritional value of the crops. Generally, the production of fruits in the region are confined to homegardens under different agro-ecologies and found in mixed plantings with little or no irrigation (BOA 1999). Nevertheless, the last decade has witnessed an emerging trend of horticulture-based homegardens especially with farmers of adequate water access. So far, except the scanty and fragmented documentation like by Conway (1988), no systematic investigation specific to homegardens and fruits growing there in have ever been made in the region in general and in the study areas in particular.

2.2.4 The roles of homegardens in gardeners' livelihood objectives

Agroforestry focuses on the role of trees on farms and in agricultural landscapes to meet the triple bottom line of economic, social and ecological needs in today's world (Garrity 2004). As a type of agroforestry system, homegardening has been a way of life for centuries and is still critical to the local subsistence economy and food security. Homegardens play numerous roles as provision of nutrition, dietary supplements, food security in times of crisis, shade, fuel wood, cash income, experimentation, aesthetics, medicinal plants and small-animal raising (FAO 1999). As gardening may be done with virtually no economic resources, using locally available planting materials, green manures, live fencing and indigenous methods of pest control, it at some level is a production system that the poor can easily enter (Marsh 1998). Many authors discussed the various roles of homegardens. Some of the pertinent literature on their major contributions in fulfilling the livelihood objectives of gardeners and the entire population is discussed as below.

2.2.4.1 Food and nutritional security, and source of income

Food production is the primary function and role of most, if not all, of the homegardens (Nair 1993). Hence, the variety of annual and perennial crops and vegetables grown in these gardens provide a secure supply of fresh produce throughout the year (Shrestha et al. 2002) and thereby contribute to household food security by providing direct access to food and important nutrients that may not be readily available or within their economic reach (Talukder et al. 2001). They are thus one strategy for addressing malnutrition and micronutrient deficiencies. For example, in Bangladesh fruits and vegetables were found the most important factor associated with higher intake of vitamin A by women of reproductive age than consumption of animal products (Bloem 1996). Similarly, Javanese gardens were estimated to provide households with about 14 percent of their total carbohydrate and protein consumption (FAO 1999). Besides, homegarden fruits and vegetables can provide other nutritional benefits, helping to prevent degenerative diseases and mortality (Mitchell and Hanstad 2004).

Unlike the seasonal harvests of staple foods from outlying fields, homegarden harvests are continuous that facilitates harvest of the required product when needed for consumption. This considerably reduces post harvest losses that can be as high as 70% due to poor storage facilities (Fernandes 2003). In addition, the garden may become the principal source of household food and income during periods of stress, e.g. the pre-harvest lean season, harvest failure, prolonged unemployment, sickness or other disabilities suffered by family members or agricultural and economic disruption caused by war (Marsh 1998). Homegardens do also provide fodder and supplies for other household needs and are a source of spices and medicinal plants. In Bangladesh, homegarden agroforestry provides about 65-70% of saw logs and about 90% of fuel wood and bamboo consumed in the country (Islam 1998). Likewise, the value of homegardens in food security is well acknowledged in the long history of Ethiopia, particularly during years of food shortage (Zemede 2001).

Furthermore, although in the majority of cases homegardens are regarded exclusively subsistence-oriented, in many cases, the sale of products produced in homegardens significantly improves the family's financial status (Mitchell and Hanstad 2004). Nevertheless, the volume of homegarden production actually sold appears to be highly variable, with studies reporting between nine and 51% of production (Hoogerbrugge and Fresco 1993; Marsh 1998). For instance, about 70% of the gardeners in Indonesia obtain some cash income from their homegardens through sales of coffee, cocoa or surplus of fruits or spices (Kehlenbeck and Maass 2004). Of course, often with an increase in selected cash crops homegardens will shift from subsistence-oriented agriculture to market economy and with the recent trends of high market-orientation they might not survive the test of time (Kumar and Nair 2004). This would lead to drastic structural and functional modifications, and use of external inputs that can lead to a loss of some of the homegardens relevance and threaten their future even to the extent of becoming dissolute or even extinct (Peyre et al. 2006). On the other hand, however, Kumar and Nair (2004) argue that the bleak futures of homegardens is unfounded as with increasing awareness and interest the world over in movements such as organic farming, ‘back to nature,’ and green consumerism, there is no reason, to abandon and denigrate everything that is traditional.

2.2.4.2 Socio-cultural significance

Socio-culturally, homegardening fits well with the traditional farming systems and established village lifestyles (Kumar and Nair 2004). Homegardens are the domain of a number of plant species that are closely linked with the culture and religion of the particular community. They offer greater security to the homestead and the trees receive good protection against damage by animals (Mitchell and Hanstad 2004). Homegardens are also a natural asset through which other livelihood objectives such as gender equality and sustainable use of resources may be achieved. In Senegal, Marek et al. (1990) found out that although the economic contribution of gardens to the household income is small, it allowed women to purchase items that are specifically important to the improvement of their social status in a society where men have the dominant position. Even in the absence of measurable nutritional effects, household gardens can play an important part in promoting social change. Trade, exchange of information and cooperation with other villagers strengthens the family's relationships with others while skills learned in production increase the family's human assets (Mitchell and Hanstad 2004). Besides, homegardens are often a haven for the family members of rural communities to relax and gather and are often focal meeting points in the communities.

2.2.4.3 Environmental and ecological benefits

Homegardens do also provide numerous intangible benefits. For instance, as they are mostly produced without pesticides they contribute to environmental protection as well as public health. Homegardens take on the character of the surrounding ecological system, and provide a place where plants, animals, insects, microorganisms and soil and air media mutually interact to maintain the agro-ecological balance while they effectively protect soil from erosion (Trinh et al. 2002). Besides, trees provide shade and clean air for the homestead and beautify the surroundings (Shrestha et al. 2002). Homegardens have a high potential for sequestering carbon as part of climate change mitigation strategies (Garrity 2004). Generally, the non-market benefits potentially provided by homegarden systems, such as biodiversity, carbon sequestration, aesthetics and ornamentation, wildlife habitat provision, are likely to be very valuable to the subsistence farmers of the tropics (Mohan 2004).

Many authors commented about the fertility of homegardens. Several agree that the homegardens possess a closed nutrient cycling much similar to the tropical forests (Nair et al. 1999; Soemarwoto and Conway 1992). For that reason, a dynamic equilibrium can be expected with respect to organic matter and plant nutrients on the garden floor due to the continuous addition of leaf litter and sometimes also deliberately through pruning (Kumar and Nair 2004), root turnover and its constant removal through decomposition as well as incomplete harvesting. Besides, the root systems of different components in the homegardens are expected to overlap considerably and the resultant higher root-length density may reduce nutrient leaching and facilitate recycling of sub-soil nutrients (Kumar and Nair 2004) as tree roots that penetrate deep can bring mineral constituents into the topsoil (Mitchell and Hanstad 2004). Moreover, more diversified agroforestry systems help alleviation of phosphorus availability from diverse litter decomposition (Gajaseni and Gajaseni 1999). Also, the multi-tiered homegarden canopy and root architecture, besides the litter layer, act as multi-layer defense mechanism against the impact of the falling rain drops resulting in low rates of soil erosion (Kumar and Nair 2004). Generally, this tree-based soil conservation system has a real promise to make money for small holders (Garrity 2004).

2.2.5 Floristic composition in homegardens

The contribution of homegardens to the maintenance of species diversity is one of their main ecological functions (Drescher 1997). Many homegardens are often diverse and complex, support very large numbers of different species interacting in the same land, and are dynamic systems. Wide variations in species assemblages of homegardens of different geographic and eco-climatic regions are apparent (Kumar and Nair 2004). Several authors documented floristic composition of homegardens around the globe (Prain and Piniero 1994; Islam 1998; High and Shackleton 2000; Méndez et al. 2001; Ariyadasa 2002; Wezel and Bendel 2003; Ahmed and Rahman 2004; Kehlenbeck and Maass 2004; Gebauer 2005).

Similarly, several studies featured the species inventory of Ethiopian homegardens especially those in the south or southwestern part of the country. Zemede and Ayele (1995) reported 162 species of plants in central, eastern, western and southern Ethiopia homegardens, of which 78 % were food crops while fruit and vegetable crops constitute 41%. Tesfaye (2005) recorded a total 120 tree-and shrub-species in Sidama homegardens with a variable frequency of species occurrence. Similarly, Zemede (2000) reported 36 fruit species in south, west and south-western part of Ethiopia. In three villages of southern Ethiopia, a total of 48 food producing plants were recorded a higher proportion of which contributed by fruit species, 11.3% (Belachew et al. 2003).

For their high levels of species and genetic diversity, homegardens are *in-situ* reservoirs for biological diversity. As an ecosystem they contain multiple levels of diversity, including cultural, genetic and agronomic diversity, and from a genetic and agronomic diversity point of view, it is often the strong influence of human beings managing the gardens that leads to increased diversity (Engels 2002). The maintenance of genetic diversity in homegardens will thus depend on farmer management, the environmental characteristics of the garden and species biology (Hodgkin 2002). Nonetheless, crop diversity is maintained in homegardens when it meets producers' needs and conservation is rarely (if ever) the actual objective. Thus, farmers who maintain diversity do so because they find it useful (Hodgkin 2002). Besides, homegardens play an important role in the conservation of unique and rare plant species, which are not found in the larger eco-system and are on the verge of extinction (Shrestha et al. 2002).

2.2.6 Factors governing floristic composition and diversity

The choice of plant species including their arrangement and management varies within and between homegardens in the same community (Méndez et al. 2001) which can be influenced by several ecological, social and economic factors (Withrow-Robinson and Hibbs 2005). Hence, the decision making processes and patterns of the farmers who practice homestead agroforestry is important in expanding and improving the practice (Salam et al. 2000) and for including homegardens as a strategic component of *in situ* conservation of agro-biodiversity. As regards the main determinants of the biotic change and variation, literature sources account it for ecological (soil, altitude, water, etc.), personal (preferences, interest, knowledge, etc.), socio-cultural and economic (household needs, gender, market, social groups, wealth status, etc.), and political factors (land use system, marketing policies, conservation policies, agricultural support systems, etc.) (Zemede 2001; Fernandes 2003). Having reviewed a range of literatures, Ali (2005) discussed that the primary aim of gardeners is to ensure basic consumption needs that is then followed by responding to prevailing market opportunities. Once the level of these demands are registered, smallholders' decision making is constrained by environmental conditions where severe environmental constraints exacerbate the intensification process, and farmers' technical and managerial skills in overcoming those constraints play a key role in achieving production goals.

Biodiversity is also closely linked with household specific needs and preferences and nutritional complementarities with other major food sources (Zemede and Zerihun 1997; Gajasen and Gajasen 1999; Vogl et al. 2002). In Soqotra island of Yemen, Ceccolini (2002) found that homegardens more rich in plant species are where the household's subsistence depends on their products while low biodiversity was encountered in villages where production was especially for the local market. It is hypothesized that urban market pressure results in decreased total species diversity while remoteness from urban centers increases species richness as subsistence production will be based on a broad variety of species. In the line of this hypothesis several authors have come up with favorable results (Kehlenbeck and Maass 2004) while others contrasted (Hoogerbrugge and Fresco 1993; Wezel and Ohl 2005). Generally, diversity seems to decrease with large share of cash crops and woodlots, high population density, labor shortage within the household and access to off-farm activities (Hoogerbrugge and Fresco 1993; Tesfaye 2005). For instance, in Bangladesh smallholders with high household populations cultivate larger numbers of species (Ali 2005).

Household attributes and access to resources seem also to have influence on floristic composition of homegardens. Homegardens in Philippines were found to correlate with the wealth status of farmers where homegardens in the lower economic strata are dominated by annual crops primarily for utilitarian purposes while those of the higher economic strata are dominated by perennial crops primarily for homesteads' beautification (Boncodin et al. 2000). Other findings show lack of continuous sufficient irrigation water (Gebauer 2005), the motivation of production, the purchasing power of the people and gender (Islam 1998; Okullo 2005; Ahmed and Rahman 2004) and availability of local materials and seeds (Talukder et al. 2001) influence species diversity. Moreover, Wezel and Ohl (2005) found that in situations where many other plant products or material are still available in the surrounding forests and are widely used, species diversity in homegardens appeared low.

Garden size was reported to markedly influence species richness and diversity in the homegardens where the greatest diversity of species was recorded in the large than small gardens (Drescher 1997; Ahmed and Rahman 2004; Tesfaye 2005). Nevertheless, density decreases as land size increases though the average total number of plants per farm is still higher in the large farms (Ahmed and Rahman 2004). Islam (1998) and Piniero (2003) suggested that low-income families with their smaller gardens tend to have more diversified crops than the high income families as the former will not have enough money to buy all their necessities so that they depend on their gardens. In addition, diversity and species compositions of gardens were reported to vary by age of homegardens (Wezel and Ohl 2005) and remoteness (Hoogerbrugge and Fresco 1993; Wezel and Ohl 2005; Kehlenbeck and Maass 2004). According to the findings of Tesfaye (2005), in Sidama zone of south Ethiopia, the closer the farm is to a road, the fewer the number of tree species, the more uneven abundance of the species and the lower the density of trees implying that the existence of roads has increased market access for the surrounding farmers.

Homegardens preserve much of the local cultural history and reveal information about plant management decisions by individual holders (Blanckaert et al. 2004). Hence, the diversity and composition of homegardens is influenced by the religious or cultural beliefs, customs and taboos of the villagers' (Millat-e-Mustafa et al. 1996; Ahmed and Rahaman 2004). For instance, in Peru native communities without any mixture from other ethnic groups or colonists living in the area and their preferences to certain cultivable species resulted in low species diversity (Wezel and Ohl 2005).

The link between species composition and diversity with environmental variables has also been widely reported. Plant diversity seems to decrease with altitude and length of dry season (Hoogerbrugge and Fresco 1993). But Tesfaye (2005) found out that within the altitudinal limits of 1520-2040m ASL, species abundance as well as density increased with altitude. Soil and climatic conditions also exert muscular influence on species richness (Hoogerbrugge and Fresco 1993; Talukder et al. 2001) where the environmental conditions are more favorable homegardens appeared richer in plant species (Ceccolini 2002). Diversity of species increases with increased amount of rainfall and temperature as it is demonstrated for humid lowland tropical areas that are very rich in species as compared to other ecological zones (Tesfaye 2005).

2.2.7 Vegetation stratification in homegarden agroforestry

In homegarden, trees, crops, animals, and people are structural and temporal components, with each having a precise place and a well-established role in time and space. Integration of animals with cropping systems provides means to sustainably intensify agricultural production and contribute to the nutrient cycling in the system (Mohan 2004). Literature pertaining to the vertical and horizontal structure of homegardens is discussed as below.

The knowledge of gardeners is beyond a simple sum of practices and floristic species to include layout structures in which specific floristic species are combined in a specific ways (Lok 2001). The structural entities are arranged in a complex micro-zonal pattern having well-defined vertical and horizontal stratification with each structural assembly occupying a specific niche (Nair and Sreedharan 1986) and having a specific function (Fernandes and Nair 1986). The multi-tired structure and combination of compatible species are the most conspicuous distinguishing features of homegardens, especially in humid tropical lowlands where most workers reported a three to six strata system with each component having a specific place as well as function (Nair 1993; Kumar and Nair 2004). This is because, gardeners design the homegardens to allow optimal harvest of solar energy through the strategy of fitting phenological classes and life forms together in space and time, and through niche diversification techniques (Zemede 2001). Their vertical structure reflects their degree of specialization and complexity (Abdoellah et al. 2002) where in the majority of cases the lower most stratum is dominated by shade-tolerant herbaceous plant species followed by shrub stratum in the middle and the tree component on the upper most layers (De Clerck and Negreros-Castillo 2000). The type and nature of the herbaceous crops has generally a remarkable similarity among the different homegardens while the nature of woody perennials varies depending on environmental and ecological factors. This is so because food production is the predominant role of most herbaceous species and the presence of an overstorey requires that the species are shade-tolerant.

The diversity and complexity of this multi-storied complex agro-ecosystem, however, varies with ecological zones, settlement patterns and sometimes socio-economic conditions; its complexity and diversity being highest in humid tropics, medium in sub-humid tropics and low in drier areas and Sahel in that order (Fernands and Nair 1986; Okigbo 1990). Various authors reported different number of vertical strata around the globe. To mention a few, three layers in Indonesia (Watson 1982) and Cuba (Wezel and Bender 2003), three to four in Ghana (Bennett-Lartey et al. 2001), Thailand (Gajaseni and Gajaseni 1999) and semi-arid Guatemala (Leiva et al. 2002) and four to five layers in India (Das & Das 2005). Also, reported were five distinct storeys in Tanzania (Fernandes et al. 1985) and six in Maya of Mexico (De Clerck and Negreros-Castillo 2000).

Ethiopian homegardens collectively maintain a larger proportion of the country's useful plants. They are unique in their architecture, crop mix and the key species, which include a significant number of indigenous crop taxa and some that are truly endemic and many other lesser-known species (Zemede 2001). In the southern Ethiopian homegardens, it ranges from complex and diverse forms containing numerous species and strata, as in Sidama area, to the less complex forms, with one or two crop/tree mixtures, as in the Gurage Enset home compound farms.

The species grown in the homegardens are distributed within the horizontal space available as well. These micro-zones are spatial areas deliberately allocated to particular species and management, as perceived by the farmer through which a better understanding of homegardens can be obtained (Méndez et al. 2001). This can be permanent like in fruit crops or temporary or cyclical as vegetables and medicinal plants (Lok 2001). While their location, size and plant species composition reflects deliberate management strategies, plants and their local uses included in these zones provide additional information on farmers' management priorities and socio-economic needs (Méndez et al. 2001). These zones often serve several purposes like helping to regulate water and humidity, labour input, soil fertility, specific climatic conditions, and minimize the damage caused by small animals kept in the gardens (Lok 2001). Okafor and Fernandes (1987) observed that trees that are used less regularly or are harder to harvest are located further from the house than those that need more protection or watering or are easier to harvest. However, the structural arrangement seems to vary with garden size (Abdoellah et al 2002) and other factors. Several authors have reported variable number of distinct horizontal zones to occur. For instance, two to six in Nicaragua (Méndez et al. 2001), three zones in Ethiopia (Zemede 2001), and five management zones in Mexico (De Clerck and Negreros-Castillo 2000) and India (Das and Das 2005). Nevertheless, in exceptional cases, Fernandes et al. (1985) found the spatial arrangement of components in a Chagga homegarden of Tanzania to be irregular and very haphazard.

A number of factors combine to determine the vegetation structure of homegardens. Generally, the structure, species composition, function, species and cultivar diversity seems to be influenced by changes in the socio-economic circumstances, marketing possibilities, cultural values, local uses, environmental and ecological conditions and or characteristics of gardens or gardeners (Christanity et al. 1986; Leiva et al. 2002; Peyre et al. 2006). In Nicaragua, Méndez et al. (2001) found that farmers' choice of specific areas for zones and their components in homegardens is based on practical considerations, plant requirements and soil conditions. In Nepal, Shrestha et al. (2002) reported that the number of vertical layers in the homegardens decreases with the increase in altitude. According to Kumar and Nair (2004), garden age and management are important factors that influence the vegetation structure where older gardens regardless of size may evolve into a multi-strata canopy structure while gardens where the litter layer is removed due to repeated hoeing or burning, ground cover development will be adversely affected. Also, the distribution of biomass shifts towards the upper strata as the homegarden matures and light becomes more limiting in the understory (De Clerck and Negreros-Castillo 2000). Besides, the structure and composition of homegardens is likely to be dependent on the gardeners' choice of species needed to fulfill their cultural, nutritional, social, and economic needs (Abdoellah et al. 2002; Lok 2001) as well as the degree of dependence on the homegarden as a source of income (Méndez et al. 2001).

2.2.8 Cultural and tree management and input utilization in homegardens

Home gardening is considered a production system that the poor can easily enter as they are run using low-inputs. This is because, according to Marsh (1998), gardens well adapted to local agronomic and resource conditions, cultural traditions and preferences are accessible to the poorest people since it relies on low-cost and low-risk technology. Literature pertaining cultural management practices of homegardens is rather scanty. However, some of the available literatures indicate that homegarden production is generally poor in terms of level of management, cultural practices and modern technology as well as extension support as evidenced by reports like in Bangladesh (Islam 1998; Ahmed and Rahaman 2004). When management practices are applied, many homegardens follow indigenous agricultural practices that are logical and rational, and have been followed for centuries (Mohan 2004). Besides, crop and animal species and varieties which are environmentally adapted are grown or bred with locally known husbandry methods with few exotic species (Hoogerbrugge and Fresco 1993). The various practices within the homegardens are determined by such factors as the species, the system and the environment (Gajasen and Gajasen 1999). Most common practices reported include weeding, spacing out, opening up the canopy, organic fertilizers and botanical pest control (Fernandes et al. 1985; Drescher 1996; Kehlenbeck and Mass 2004; Ali 2005; Peyre et al. 2006).

As a result, the capital and energy inputs in gardens are generally low (Hoogerbrugge and Fresco 2003) and homegardens are maintained with a minimum of purchased inputs (Marsh 1998). Hence, homegardens are regarded better in nutrient status (Gajaseni and Gajaseni 1999) and the use of synthetic fertilizers is in most cases limited. Besides, in homegardens with relatively high genetic and species diversity neither single incident of a pest outbreak at a threatening level nor any chemical compound used for pest and weed control (Gajaseni and Gajaseni 1999). Nevertheless, Hoogerbrugge and Fresco (2003) commented that traditional techniques do not suggest that age-old techniques are always applied, but that modern cultural practices (agro-chemical inputs in particular) are used infrequently or occasionally, depending on individual household strategies. To this end, only little evidence exists on the use of chemical fertilizers and pesticides at minimum level in homegardens like that of Bangladesh (Ali 2005) and Zambia (Drescher 1997).

The water cost of homegardens seems also low. In Thailand, Gajaseni and Gajaseni (1999) found out that the homegardens to have more favorable micro-environments with lower soil and atmospheric temperature and higher relative humidity than the outside, as a result of which less soil evapotranspiration and thus retention of more water happens in the homegardens. This, ofcourse, may need to be seen interm of the water use of the whole system. The labor for gardening is nearly always provided by household members instead of hired or exchanged labor (Fernandes and Nair 1986; Nair 993; Hoogerbrugge and Fresco 2003). In Kerala, India, Mohan (2004) found out that despite almost all the gardens to hire labor especially for the more arduous tasks, the bulk of the labor input comes from the members of the household. Likewise, Peyre et al. (2006) reported that fruit tree management practices are minimally practiced in these homegardens. In total, the low utilization of external inputs is suggestive of the sustainability of the homegarden production system.

3 Material and methods

3.1 The study area

3.1.1 The Amhara region

The study was undertaken within six districts in western part of Amhara region of Ethiopia in two rounds of field work between July 2006 and January 2007 and January to May 2008. Forming one of the nine federal states of Ethiopia, the Amhara National Regional State is located between 9^0-14^0 N and 36^0-40^0 E in the northwest of the country and covers an area of 159,173.66 km^2, which comprises 11% of the total area of the country (Figure 3.1).

The region is divided into 11 administrative zones and comprises of 105 districts. The regional capital, Bahir Dar, is situated on the southern shore of Lake Tana some 565 kms away from Addis Ababa. Topographically, the Amhara Region is divided into highlands, the amazing Semen Mountains in the north and massive mountain ranges in the east and west, and lowlands in the northwest including the low-lying Nile Basin. As per the local agro-ecological zone classification, the region is divided into *Kolla* (31%), *Woinadega* (44%) and *Dega* (25%) climates[*]. The mean annual temperature is between 15^0C and 21^0C though the temperature exceeds 27^0C in valleys and marginal areas (ADA 2003). Based on the results of the October 1994 National Population and Housing Census, the total projected population of the region as of July 2006 is estimated at 19,120,005 (9,555,001 men and 9,565,004 women) with a density of 120.12 people per square kilometer where 88.5% of the total population live in rural areas (CSA 2005).

3.1.2 Geographical location of the study areas

The wild and garden fruit studies were conducted in separate locations depending on the perceived potential and constraints of the respective locations. Accordingly, the wild fruit studies were undertaken in Adiarkay, Debark and Dejen *Woreda*s (= hereafter alternatively used with districts). Part of the North Gondar Administrative Zone, Adiarkay and Debark are located adjacent to each other at the northeastern and western fringes of the slopes of the Semen Mountains and bordered by Tigray region in the north, east and northwest and the eastern border of Adiarkay defined by the Tekeze River. The *Woreda*s' capitals, Debark and Adiarkay (named after their respective districts), are situated along the Addis Ababa-Mekelle road 835km and 903km away from Addis Ababa and 280km and 360km from Bahir Dar, respectively.

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[*] “ *Kolla*” refers to warm semi-arid lowlands (< 1500m asl, 20-27.5 C°, 200-800mm rain);
“*Woinadega*” = temperate cool sub-humid highlands (1500-2300m,16-20.5 C°, 800-1200mm);
“*Dega*” = cool humid highlands (2400-3200m, 11.5-16 C°, 1200-2200mm), Source: MOA (2000).

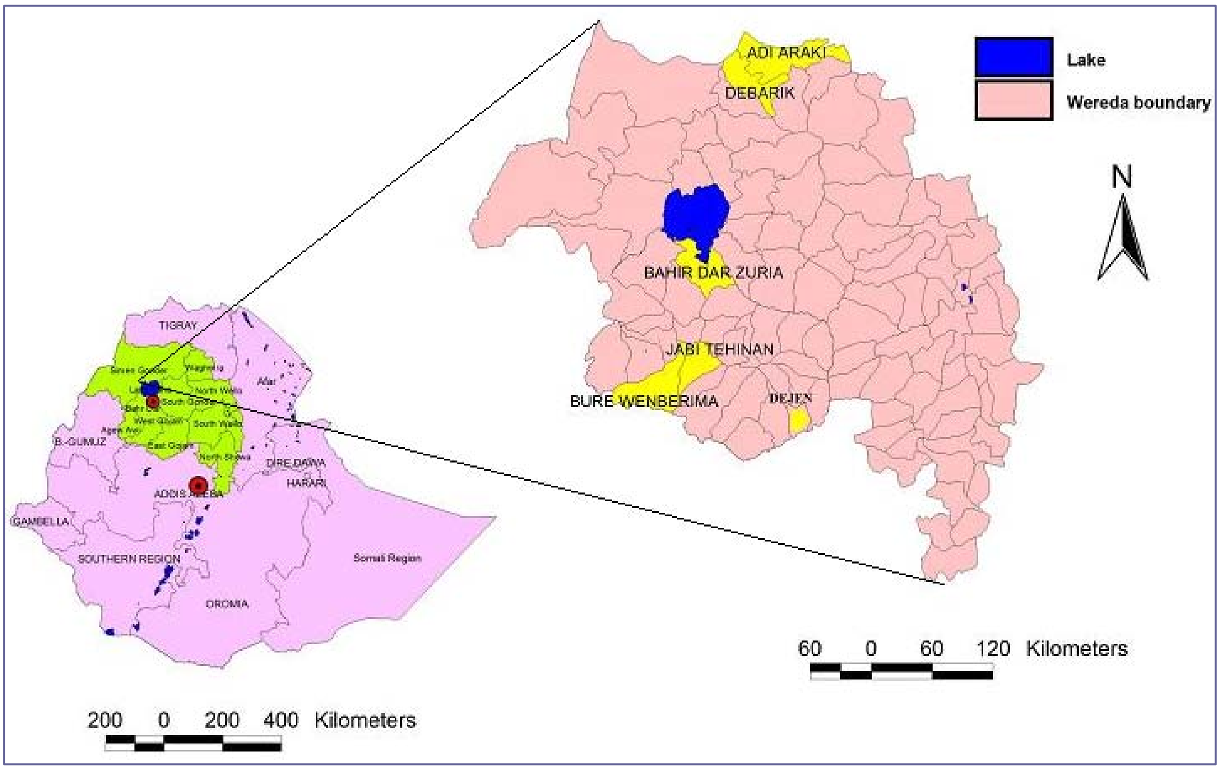


Figure 3.1: Map of the study area (left = Ethiopia; right = Amhara Region and the study *Woreda*s -yellow tinted)

The Dejen *Woreda* is located at the southwestern most end of East Gojjam Administrative Zone delimited by the Blue Nile River which separates it from the Oromiya Region (Figure 3. 1). The *Woreda*`s capital, Dejen, is located 230km away from Addis Ababa along the highway leading to Bahir Dar. Adiarkay and Dejen *Woreda*s form the Northern and Southern ends of Amhara State and delineate it respectively from Tigray and Oromiya regions.

The elevation constitutes diverse altitudinal zones ranging from about 1,000 to 4,200m ASL and roofed by Mount Ras Dejen (4,620m). The relief at Adiarkay and Debark is for most part mountainous with rugged ridges and ravines. In Dejen, the local relief is both plateau and mountainous with valleys and gorges in the lowlands. These *Woredas* were chosen because they composed of sites that fully or partly figuring among the chronic food insecure areas periodically facing food shortages due to their fragile environmental setting. Besides, especially in Adiarkay and Debark *Woredas* people economic activities have a direct influence on the endangered world heritage site, the Semen Mountains National Park.

The homegarden fruit studies were conducted in Bahir Dar Zuria, Bure and Jabi Tehnan *Woredas* of West Gojjam Administrative Zone. Bahir Dar Zuria *Woreda* surrounds the Bahir Dar town. Bure and Jabi Tehnan *Woreda*s are adjacent to each other and lie southwest of Bahir Dar along the highway leading from Bahir Dar to Addis Ababa with their capitals, Bure and Finoteselam located 148 and 173 kms away from Bahir Dar. The topography is for the major part plain and the elevation ranges between 1,300 and 2,350 m ASL. These *Woreda*s were chosen because of their history of horticultural crops production practices and better access to market and transportation (Table 3.1).

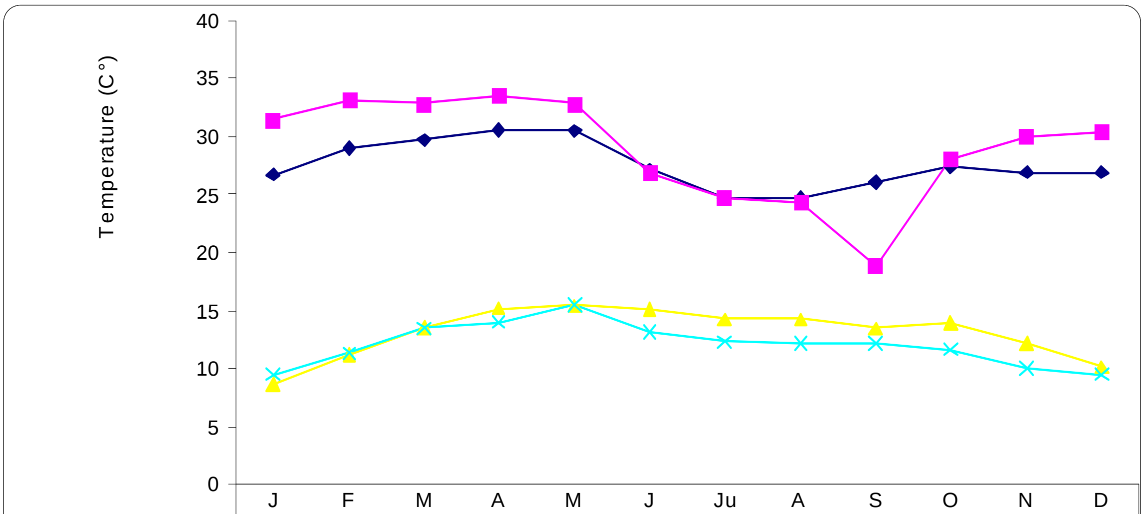
Table 3.1: Geographical location, climate and soils of the study *Woreda*s

Woreda	Latitude	Longitude	Altitude	Average total rainfall	Average monthly maximum temperature	Average monthly minimum temperature	Relative humidity	Soil types (percent coverage)								
	°N	°E	Meters	mm	(°C)	(°C)	(%)	Leptisol(l)	Acrisols	Cambisols	Lithosols	Nitosols	Phaeozems	Rendzinas	Vertisols	Luvisols
Adiarkay	13.25	38.02	943 - 3200	1343.9	27.6	13.3	na	48.2	0.0	51.8	0.0	0.0	0.0	0.0	0.0	0.0
Debark	13.08	37.54	1000 - 4200	1033.2	19.9	8.9	53.5	0.0	48.5	25.2	11.0	3.4	11.8	0.0	0.0	0.0
Dejen	10.13	38.08	1080 - 2576	1110.9	na	na	na	0.0	0.0	0.0	0.0	20.1	0.0	40.0	39.9	0.0
Bahir Dar	11.35	37.23	1300 - 1750	1507.1	27.7	13.2	55.3	0.0	0.0	0.0	2.1	0.0	3.3	0.0	17.8	76.9
Bure	10.42	37.04	700 - 2350	1581.0	25.0	17.0	na	0.0	12.1	40.0	0.0	47.9	0.0	0.0	0.0	0.0
Jabi Tehnan	10.40	37.15	1500 - 2300	1250.0	29.0	12.3	56.7	0.0	0.0	24.1	0.0	75.9	0.0	0.0	0.0	0.0

Source: Bahir Dar metreology station and *Woreda* Agriculture and Rural Development offices of respective sites

3.1.3 Climate, soil and geological formation of the study areas

Climatically, Adiarkay and Dejen have a warm temperate climate that tends to be hot to warm moist or *Kolla* towards the specific study sites (Tables 3.2 & 3.3). On the other hand, most part of Debark is a cool highland. However, under the country's new agro-ecological classification the major parts of all the three *Woredas* fall under tepid to cool moist climate. Similarly, Bahir Dar Zuria and Jabi Tehnan *Woredas* are predominantly characterized by tepid to cool moist climate or *Woinadega* while most part of Bure *Woreda* falls under hot to warm climate and belongs to the *Kolla* and *Woinadega* zone. The study site at Bure entirely belongs to the *Woinadega* zone. Generally, the temperature is milder in the homegarden (Figure 3.2) than wild fruit study *Woredas*. Although most parts of the wild fruit study *Woredas* receive a good amount of rainfall, its distribution especially in the lowlands is so erratic characterized by late onset and early termination and sometimes a complete failure resulting in a frequent crop failure. In contrast, the garden fruit study areas receive a good amount of rainfall that is uniformly distributed over four to five months of a year (Figure 3.3).



	J	F	M	A	M	J	Ju	A	S	O	N	D
Bahir Dar-maximum	26.8	29.0	29.8	30.6	30.5	27.2	24.8	24.8	26.1	27.4	27.0	27.0
Lai Bir-maximum	31.4	33.1	32.9	33.6	32.8	26.9	24.7	24.4	18.9	28.1	29.9	30.4
Bahir Dar-minimum	8.6	11.2	13.5	15.2	15.4	15.1	14.3	14.2	13.5	13.9	12.2	10.1
Lai Bir-minimum	9.5	11.4	13.5	14.1	15.6	13.2	12.3	12.2	12.2	11.6	10.0	9.5

Figure 3.2: Mean monthly minimum and maximum temperatures of the homegarden fruit study areas, Bahir Dar and Jabi Tehnan (= Lai Bir)

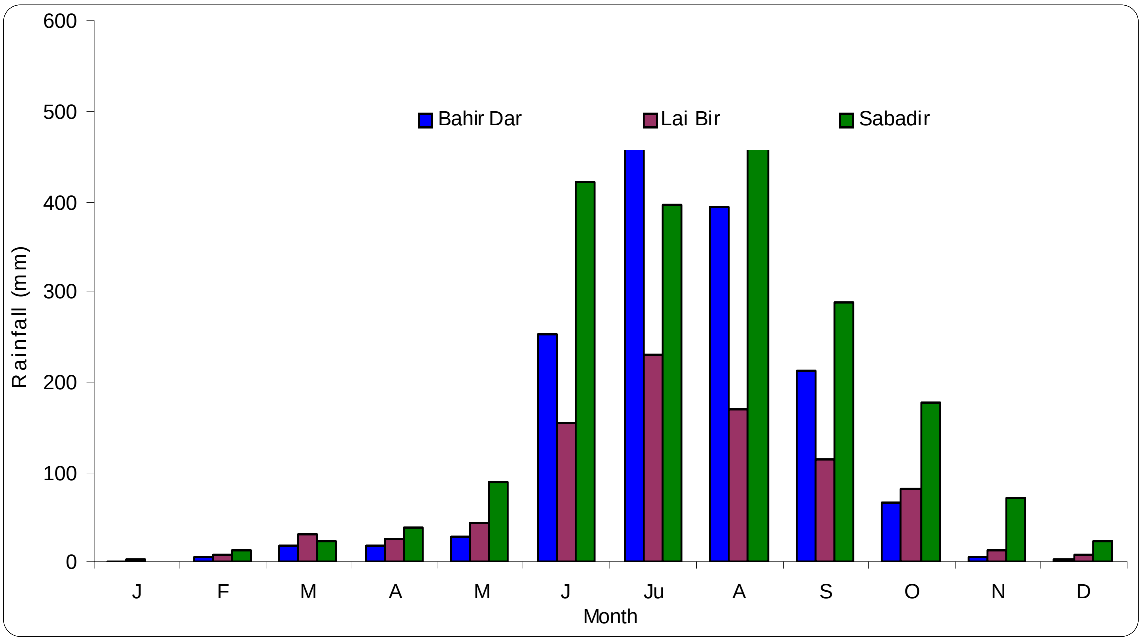


Figure 3.3: Mean monthly total rainfall pattern of the homegarden fruit study sites (Bahir Dar, Jabi Tehnan (= Lai Bir) and Bure (= Sabadir)

Diverse soil types exist in the study areas the dominant types being Cambisols and Leptosols (I) in Adiarkay, Acrisols in Debark and Rendzinas and Vertisols in Dejen. The greater part of Bahir Dar *Woreda* is covered by Luvisols, that of Jabi Tehnan by Nitisols and Bure by Nitisols and Cambisols. Geologically, most parts of Adiarkay and Debark are a formation of tertiary plateau volcanoes while the Dejen area is a formation of Mesozoic sedimentary rocks (BoPED 1999).

Table 3.2: Percent agro-climatic zone coverage of the study *Woredas* based on the contemporary ∗ and traditional classification systems

Woreda	% coverageunder new classification									% coverage under traditional classification			
										Kolla	Woina Dega	Dega	Wurch
	SM1	SM2	SH3	M1	M2	M3	SH1	SH2	Tepid moist	(500-1500m)	(1500-2300m)	(2300-3200m)	(3200m+)
Adiarkay	0.0	10.0	8.0	19.9	53.7	16.0	0.0	0.0	0.5	24.4	43.5	20.6	11.6
Debark	0.0	0.0	0.0	3.0	81.0	16.0	0.0	0.0	0.0	14.4	47.5	34.1	4.0
Dejen	0.0	0.0	0.0	22.0	78.0	0.0	0.0	0.0	0.0	25.4	37.7	36.9	0.0
Bahir Dar	0.0	0.0	0.0	0.0	86.0	14.0	0.0	0.0	0.0	0.0	100.0	0.0	0.0
Bure	0.0	0.0	0.0	63.0	27.0	0.0	9.0	0.0	0.0	41.2	52.3	6.5	0.0
Jabi Tehnan	0.0	0.0	0.0	10.0	90.0	0.0	0.0	0.0	0.0	2.9	92.0	5.1	0.0

Table 3.3: Geographical location and altitude of the study sites

	Debir	Dibbahir	Bermariam	Adiaregay	Kurar	Andassa	Robit	Wogelsa	Zeghe	Wangedam	Woinma	Arbayitu
Latitude (N)	13.15	13.24	13.40	13.45	10.08	11.29	11.68	11.62	11.69	10.70	10.54	10.63
Longitude (E)	37.92	37.89	37.00	38.06	38.19	37.29	37. 45	37.28	37.31	37.11	37.16	37.27
Altitude (meters)	2885	2116	1620	1553	1360	1730	1853	1820	1760 - 1960	2040	1600	1808

Source: Field records and Agricultural Development Agent offices of respective sites

3.1.4 Socio-economic and cultural background of people

Based on figures published by the Central Statistical Agency of Ethiopia (CSA 2005), population estimates of Adiarkay, Debark and Dejen *Woreda*s totals to 146,751 (73,004 male

∗ SM1 = Hot to warm sub-moist; SM2 = Tepid to cool sub-moist; M1= Hot to warm moist; M2 = Tepid to cool moist; M3 = Cold to very cold moist; SH1 = Hot to warm sub-humid; SH2 = Tepid to cool sub-humid; SH3 = cold to very cold sub-humid.

and 73,747 female), 168,100 (84,372 men and 83,728 women) and 121,296 (62,630 men and 58,666 women) in that order. On an estimated area of 2,231.90, 1,512.22 and 628.56 km^2, in these *Woreda*s 65.8, 111.2 and 193 people reside per km^2. As regards land allocation, at Adiarkay 18.5% of the land is cultivated, 17.1% pasture, 3.4% forest, 45.7% bush, 3.1% park and 1.2% constructed while 6.4% is unused. At Debark, some 25.8% is cultivated, 6.7% pasture, 30.8% forest and 35.4% bare land. Bahir Dar Zuria, Bure (including the former Wonberma) and Jabi Tehnan *Woreda*s respectively house an estimated total population of 270,013 (132,634 male and 137,379 female), 296,398 (149,343 male and 147,055 female) and 272,026 (136,042 male and 135,984 female). With an estimated area of 2,062.62, 2,207.20 and 1,230.94 km^2, their population densities figure at 130.9, 134.3 and 221 people per Km^2.

Agriculture has a long history of spanning, more than three thousand years, in the study areas which is insufficiently operating. The majority of inhabitants rely overwhelmingly on Agriculture for their livelihood and practice similar economic activities of mixed farming (crop production and livestock raising). Cultivation of subsistence cereal crops is the mainstay of the people that also dominate their diet. Thus, people are generally poor and especially at Adiarkay and Debark quite a large populace manages to survive on supplementary food aid. On contrary, in the homegarden study *Woredas* apart rain-fed agriculture there is a good opportunity for irrigated culture. People are in a great advantage of favorable climate, water access and diversified activities. Especially, the Bure and Jabi Tehnan *Woredas* are known to be high potential agricultural areas. As a result, people tend to be in a relatively better living status than those farmers in the wild edible fruits study areas are.

Despite their neediness, however, peoples' principles are very strong and are proud of their culture, religion, ethnicity and identity. Christianity is the dominant religion in which Orthodox Christians form the majority. Islamic people are generally few in the rural settings. Others include, few Catholics and Protestants of different sects. Linguistically, they are Semitic and all speak their mother - tongue, Amharic, which is the regional as well as national official language while a few are bi - lingual (Amharic & Tigrinya). Hence, with a few Tigre and other ethnic groups, the majority of inhabitants are Amhara nationals.

3.2 Site selection and Sampling

For the wild fruits study, three *Woredas* which for their fragile environment are known to comprise *Kebele*s (= Peasant Associations, hereafter alternatively used with sites) that utterly or partially sustain chronic food insecurity and facing periodic food shortages were selected in consultation with local agricultural experts. From each *Woreda*, one to two representative *Kebele*s were chosen based on proximity to the existing remnant forest resources and representativeness of the different agro-ecologies while their number was determined based on size of the locality, perceived variability and cost considerations. Accordingly, a total of five *Kebele*s (two from Adiarkay, two in Debark and one in Dejen *Woreda*) were chosen. Adiaregay, Bermariam and Kurar represent the *Kolla* agro-ecological zone while Dibbahir and Debir represent the *Woinadega* and *Dega* zones, respectively. From the sample frame of household heads of each *Kebele*, 10-20 households were randomly chosen (Figure 3.4).

In sites where women headed households were not adequately represented in the randomization processes for their low number in the community, they were directly included by randomly reducing the number of male-headed households. The number of sample informants varied based on number of inhabitants and the amount of variability anticipated. Thus, except at Kurar where only ten households were sampled, in all the other *Kebele*s 20 households each were randomly chosen that totals to 90 household head informants (85% men and 15% women). The study was guided by agricultural development experts from the respective *Woreda* and *Kebele* offices.

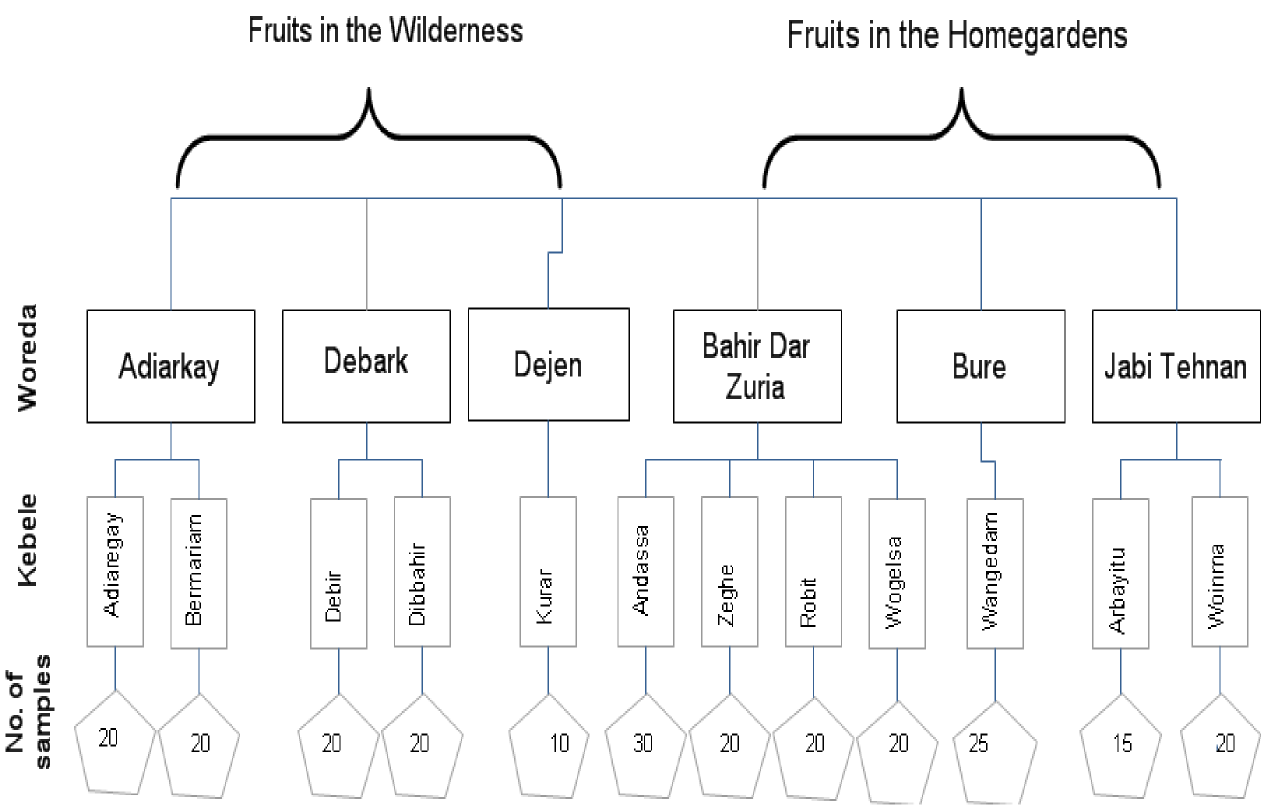


Figure 3.4: Sampling procedures of sites and informants

*Kebele*s for the homegarden fruits study were chosen based on horticultural crops production experience criterion. Accordingly, in each *Woreda* one to four *Kebele*s were selected that add up to seven (four in Bahir Dar Zuria, one in Bure and two in Jabi Tehnan). The number of sample *Kebele*s varied depending on the availability of fruit-based gardeners that are easily accessible. Further, in each *Kebele* specific villages had to be chosen in consultation with agricultural Development Agents (DAs), since not all villages practice fruit-based homegarden production. From a sample frame of household heads list of each *Kebele*, 15-30 informants were randomly chosen with reasonable gender representation; 30 at Andassa, 20 each at Wogelsa, Robit, Zeghe and Woinma, 25 at Wangedam and 15 at Arbayitu, totaling to 150 informants. Therefore, the study bases at 90 and 150 household head informants respectively for the wild and domesticated fruits investigation. But depending on the requirement of specific parts of the study the number of informants for the wild fruit study sometimes goes up to 104 informants.

3.3 Data collection

3.3.1 Survey and Interviews

Prior to commencement of the main study, secondary data was collected about the background and general information of the study areas from archives and by interrogation from different organizations and individuals. Both qualitative and quantitative approaches were employed. For collecting primary data, structured and semi-structured interviews were administered to document informants' attributes, enumerate floristic composition and understand people's practices, opinions, attitudes, preferences, priorities, and or perceptions.

3.3.1.1 Interviews

In the semi-structured interview, all interviewees were asked the same standard questions in the local Amharic language in a one-to-one basis using open- and close-ended questionnaires. Then, following and depending on the answers a series of specific questions were asked on the subject of interest including expansions upon or clarifications as needed. After pre-testing with few informants, in-depth household head interviews were also administered using structured questionnaires on questions of binary and multiple answers interest. Interviewees were visited at their working places or their homes. Besides, key-informants who were anticipated to have a particular insight or opinion about the subject under investigation were interviewed from Bureau, *Woreda* and *Kebele* levels by means of semi-structured interviews using a checklist of questions.

3.3.1.2 Focus Group Discussions (FGDs)

Focus Group Discussions were employed for wild fruits investigation to help comparison of patterns evident among individual interviews and reconcile contradictory information among informants. Accordingly, discussions were undertaken in groups consisting of eight to ten people in three selected *Kebele*s. Involved in the discussions were prominent elders of both sexes, youngsters and children (cattle herders and students). Open-ended discussion guidelines were employed and the discussions chaired and recorded verbatim by the researcher.

3.3.1.3 Direct observation

Besides, direct observations of wild fruits was undertaken in accompanying excursions to the different niches so as to observe the plants cited, to collect samples for posterior botanical identification, soil samples and fruits for analysis, to identify site conditions and characterize the plants. These walks were also taken an opportunity to visit people at their farms and opportunistically at any occasion the researcher spent time with people elsewhere. In addition, in a guided tour through the homegardens direct observations were employed to identify micro-zones, vertical stratifications, plant spacing, intercropping practices, etc.

3.3.2 Wild fruits cultural domain, local knowledge and species preference

Elements of wild edible fruits cultural domain were elicited through a free-listing technique. In this technique informants were asked independently the same question to freely name all the wild edible fruit species they know as it comes into their memory and their answers noted verbatim carefully as per the given order as per Puri and Vogl (2005). In this way, a total of 104 informants stratified by age and sex were interviewed orally across the study areas. Data were also gathered on informant attributes like age, gender, education status, number of children, etc. so as to assess their relationship with informants' wild fruit species knowledge. Reflections on species preferences of people were directly assessed through individual interviews. Besides, groups of farmers exercised pair-wise rankings to prioritizing the most preferred species.

3.3.3 Species inventory and identification

Wild fruits species richness and diversity at the working landscape was carried out by reaching all farms of selected households and counting all available species along with their numbers. Any edible fruit bearing tree, shrub or climber growing higher than 1.5 meters (Beentje 1994) was recorded along its specific agricultural niches, tree characteristics and all other necessary plant and site information. In homegardens, complete inventories were carried out to assess the type and number of fruit species and varieties, types of other perennial tree and shrub species, live fences, annual crops and ornamentals. All fruit species of a year old and above were recorded along with their number. This was done with the help of enumerators that were given the necessary awareness and training.

Most of the recorded wild fruit species were identified on the spot with the help of farmers, agricultural development agents and experts, by referring literatures and using own experiences. For species which could not be confirmed on spot voucher specimens were collected and confirmed at the National Herbarium, Addis Ababa University where the specimens were also deposited at.

3.3.4 Assessing marketing potential of wild fruits

An all year round record of wild fruits was made at fortnight intervals at two *Woreda* town markets, Adiarkay and Debark with the help of trained data enumerators. The methodology outlined by Clark and Sunderland (1999) was followed and wild fruit stock-taking of market stands were undertaken. The type of fruit species and amount marketed, prices, number of people involved in transactions and their personal attributes, baggaging, etc., were all recorded. Besides, interviews were administered with selected vendors and customers.

3.3.5 Fruit sample collection and nutrient analysis

Ripe fruits of priority wild fruit species were collected from different trees in triplicates. Fresh weights were recorded immediately after harvest and kept under shade until they are fully dried. Then, dry weights were recorded and submitted for analysis to the Ethiopian Nutrition and Health Research Institute, Addis Ababa. Fruits were analyzed for the contents of fat, protein, fiber, ash, carbohydrate, phosphorus, vitamin C and iron.

3.3.6 Soil sample collection and analysis

In order to get clues on the effects of wild fruit bearing tree species on farm soil fertility, soil samples were collected in duplicates in the rhizosphere and out of the trees' crown projection area within the top 20cm depth on trees included in farms. Accordingly, five samples were collected and composited for analysis in each category that totals to ten soil samples per tree per species. Similarly, soil fertility of homegardens were judged by collecting soil samples in duplicates within and outside the domain of gardens, the later serving a control. Hence, five samples were collected and composited for analysis per garden in five gardens per site. Both the wild fruit and garden samples were submitted to Bahir Dar soil testing Laboratory and analyzed for physical and chemical properties (Total nitrogen, Available phosphorus, Organic carbon, pH, Cation Exchange Capacity and Texture) using standard procedures.

3.4 Data processing and analyses

Data from the field study were analyzed both qualitatively and quantitatively. Responses from open-ended questions were grouped into classes that expressed similar ideas while percentages, based on valid responses only, were calculated from close - ended questions. Results were compared among households, *Kebele*s, *Woredas* or agro - ecologies and niches. Data were submitted to analysis of variation using different statistical softwares: SPSS for windows version 15, ANTHROPAC 4.0 (Borgatti 1992) and Biodiversity R. (Kindt and Coe 2005) built on the free R 2.1.1 statistical program and its contributing packages (R Development Core Team 2005).

3.4.1 Species composition and diversity

3.4.1.1 Species richness and diversity

Total species richness was calculated just by counting the number of species in a given sampling unit. However, average species richness, which is the pooled species richness when all sampling units are combined together, was calculated using sample-based exact species accumulation curves as per Kindt and Coe (2005). These curves portray the trend in which additional species are encountered when a larger area is sampled.

Diversity indices provide important information about rarity and commonness of species in a community by offering a summary of richness and evenness in a single statistic. In the present study, Shannon Diversity Index was used as diversity indicator that takes a value of zero when there is only one species in a community and a maximum value when all species are present in equal abundance.

Shannon Diversity Index (H) was calculated as (Magguran 1988):

$$H = -\sum Pi * \ln Pi$$

where, *H* = Shannon Diversity Index; *Pi* = proportion of individuals found in the i^{th} species; *ln* = is the natural logarithm of this proportion.

Evenness (E) was calculated as the ratio of observed diversity to maximum diversity as Pielou (1969):

$$E = \frac{H'}{\ln S}$$

where, H' = Shannon diversity index; S = species richness

3.4.1.2 Species diversity pattern and ordering

Relative species abundance, which is the abundance of a species as percentage of the total abundance of all species, was calculated using rank-abundance curves. These curves help ranking species in decreasing order and describe the pattern of diversity.

Rényi diversity profiles are one of the diversity ordering techniques that, apart from providing information on species richness and evenness, offer a chance of ordering communities in diversity (Tóthmérész 1995). Similarly, Rényi evenness profiles offer a more direct method of comparing evenness on a graphical presentation. Accordingly, Rényi diversity and evenness profiles were employed to ordering sites and niches in diversity and evenness in that order following Kindt et al. (2006).

Rényi diversity profiles:

$$H\alpha = \frac{\ln\left(\sum Pi\alpha\right)}{1-\alpha}$$

where, H_α = Rényi diversity profile; *Pi* = proportional abundance of a species; α = scale parameter with values 0, 0.25, 0.5, 1, 2, 4, 8 and ∞.

The values at α = 0, 1, 2 and ∞ correspond to species richness, Shannon diversity index, reciprocal Simpson and Berger-Parker diversity indices. In such profiles, a site of higher diversity than a second site will have a diversity profile that is everywhere above the profile of the second site (Tóthmérész 1995).

Rényi evenness profiles:

$$\ln E\alpha,0 = H\alpha - H0$$

where, ln Eα, 0 stands for evenness profile; Hα is diversity and H0 species richness

The contribution of the dominant species and the other species to evenness was judged by the value at E∞ and the ratio of E1 to E∞, respectively (Kindt 2002).

3.4.1.3 Species relative frequency and density

Relative frequency, which is taken to mean the number of occurrences of a species as a percentage of the total occurrences of all species, was calculated as number of plots with the species divided by the sum of occurrences of all species multiplied by hundred.

Species or tree density, which is the number of species or trees per unit area, can give a clue on the planting and cultivation patterns of farmers while it also helps to assess the effect of land size on species diversity. Hence, density was calculated both at farm level, where the total number of species or trees was divided by the size of the farm, and at site level where the total number of species or trees were divided by the total area of all farms of a site.

3.4.1.4 Species composition comparison and classification of sites

Species composition similarities and differences of sampling sites and agro-ecologies were compared based on ecological distances. With distance measuring methods constrained within the 0-1 interval, when distance between two sites is “0” the two sites are considered completely similar for every species while the value “1” indicates their complete dissimilarity (Kindt and Coe 2005). In this study, species similarity of sites (Beta Diversity) was judged using Sorenson index proposed for qualitative data as (Magurran 1988):

$$D = \frac{2j}{a+b}$$

where, D = distance; j = the number of species found in both sites; a = the number of species in site A, and b = number of species in site B. The results were then subtracted from unity to show in terms of distance or dissimilarity value.

Bray-Curtis distanced average linkage hierarchical agglomerative algorithm was employed to see if there is any tendency of grouping among sites and farms based on binary species data. Principal Component Analysis (PCA) and Principal Coordinate Analysis (PCoA) ordination techniques were also resorted to support the cluster analysis.

Besides, to explore clusters among the wild fruit species in terms of co-occurrence in the free-lists, a non-metric dimensional analysis (NMDS) technique was employed.

3.4.1.5 Factors influencing propensity of domestication and farm species composition

The propensity of farmers to plant fruit trees and variability in farm diversity of fruit species were modeled using General Linear Modeling (GLM) approach. A GLM is characterized by link and variance functions, which respectively describe how the mean of the response variable depends on the explanatory variables and how the variance of the response variable depends on the mean. A GLM is thus defined by (Kindt and Coe 2005):

$$Link\ \ function: g(\mu) = a + b_1 x_1 + b_2 x_2 + b_3 x_3 + \Lambda$$

$$Variance\ function: \mathrm{var}(y) = \theta\, x\, V(\mu)$$

where, μ = mean of the response variable y; x = explanatory variable; a & b = regression coefficients; var = variance; θ = dispersion parameter which its value is equal to, greater or less than one in a random (Poisson model), clumped or regularly distributed population, respectively.

To understand factors affecting the propensity of farmers for domestication of wild fruits a quasi-binomial variance function fitted with a logit link on binary data (presence or absence of fruit species) was used as the dependent variable and a number of measurable covariates. The logit link function guarantees that the predicted values will be between 0 and 1.

The logit function is defined as (Kindit and Coe 2005):

$$\log it\ (\mu) = \frac{\log(\mu)}{1-\mu} = a + b_1 x_1 + b_2 x_2 + b_3 x_3 + \Lambda$$

The correlation of explanatory factors with species richness and diversity was tested based on Pearson's correlation coefficient. Then, the potential influence of correlated explanatory factors on species richness and abundance of individual farms was analyzed using Poisson, quasi-Poisson and negative binomial GLM variance functions fitted with a log link to the observed number of species and trees, respectively (Jongman et al. 1987). Similarly, negative binomial GLM was employed to assess informants' knowledge of edible species using free-list length a proxy.

3.4.2 Cultural domain and informant consensus

Analysis of the cultural domain, consensus analysis and related aspects were all done based on the free-list data that was analyzed automatically by the ANTHROPAC software following Borgatti (1996). To determine the cultural domain of wild fruits, species mentioned by two or more informants were considered for inclusion. Smith's saliency index, S (Smith 1993), which takes into account both the frequency of mention of each fruit species and the order it was mentioned by each informant, was calculated as a measure of saliency.

To calculate Smith's saliency index, first species listed by each informant were ranked inversely and the inverted rank of each species is divided by the number of species in the free-list. These salience scores are summed over all the free-listers for each species and divided by the number of informants to come up with the composite salience.

The free-list data was dichotomized into a matrix of informants by each of the species and used to analyze the similarity of species using positive matches as a measure of similarity. This data was inputted to construct fruit cluster diagram and a multidimensional space map so as to produce a visual picture of the relationships among species. From the free-list data, estimated knowledge of each respondent, estimated correct answer for each question and a key of species that can be considered as members of the domain were also outputted. Based on this, insight into informant consensus, shared knowledge of informants and possible cultural variations was obtained.

3.4.3 Ethno-ecological importance of agricultural niches

Ethno-ecological importance value was calculated to linking cultural information to ecological data. This helps to understand the contribution of different niches in the agricultural landscape as a source of wild fruit species. Ethno-ecological Importance Value (EIV) was calculated following Castaneda and Stepp (2007) as:

$$EIV = \sum_{x=1}^{N} (S)\left(\frac{nx}{Nx}\right)$$

where, N = total number of species in all niches; S = Smith's Saliency Index; n_x = total number of individuals of species "x" found in one niche; N_x = the sum of species "x" found in all niches.

4 Results

4.1 Wild fruit species composition in the total landscape

4.1.1 Species taxonomy, life forms and habitats

The study documented a total of 48 species of wild edible fruit bearing plants that are classified among 32 genera and 24 families (Table 4.1). Nevertheless, the local nomenclature recognizes only 42 of these species. This is because in the folk classification one vernacular name is often used to refer to multiple species. Particularly distinction is not made among species belonging to the genera Carissa, Ficus (three species), Rhus, Rubus and Ziziphus (two species). Conversely, multiple vernacular names are sometimes assigned to a single species. For instance, *F.virosa* and *T.indica* are respectively known each by double names "*Ayihada*" or "*Bit*" and "*Roka*" or "*Humer*" depending on the location. Generally, some 34 species (70.8 %) are known by two or more names. While some of these names are simply dialects several others are due to cultural differences among people of the different sites. This suggests that relying only on folk classification as a basis for diversity assessment is not sufficient and needs to be cross- checked with scientific nomenclature.

The greatest contribution of edibles comes from Moraceae family, which it is represented by five species, the runner-ups being Rhamnaceae and Tiliaceae each with four species. Thirteen families (30%) are represented by only one species (Figure 4.1). The richest genus is Ficus that comprised of five species followed by Grewia and Ziziphus with three species at par. However, the genus or a family with the larger species did not necessarily translate into most important as some of the species, for example, *Ficus vasta* in Moracae family, are trivial. In the study, it was also found out that species known in cultivation like *Citrus* spp. and *Coffea arabica* sometimes grow in the wilderness especially in churchyard and monastery forests.

Besides, tree-to-tree (intra-specific) variations that are expressed in terms of differences in fruit attributes and other plant parts were largely recognized by informants in several fruit bearing species. For instance, variabilities are known in taste (*D.mespiliformis, C.spinarum, R.abyssinica, S.guineense* and *Z.mucronata*), size (*M. kummel, T.indica, C.spinarum, R.abyssinica, S.guineense, Rubus* spp. and *C.africana*), flesh thickness (*C.africana, S.guineense* and *P.reclinata*), shape (*C.spinarum, M. kummel, T. indica*), color (*Rubus* spp. and *S.guineense*) and maturity (*D.mespiliformis* and *D.abyssinica*).

Nonetheless, such morphological variabilities might not be entirely ascribed to genetic differences in all cases. Rather, site factors seem to have a great role to play. For instance, tamarind trees growing on upper slopes tend to have short stature and smaller fruits than those at the low lying slopes and valley bottoms. In *S.guineense*, riverine trees are regarded less tasty than those in other niches. Similarly, size variabilities in *R.abyssinica, Rubus* spp. and *S.guineense* mainly arise from site conditions. Trees located on fertile sites tend to be robust and bear larger fruits than those in less fertile sandy soils. In *D.mespiliformis*, trees on uplands fruit early in December while those grown by river sides come to fruiting late in March to May. The findings underpin the need for assessing contribution of genetic factors to the observed phenotypic differences.

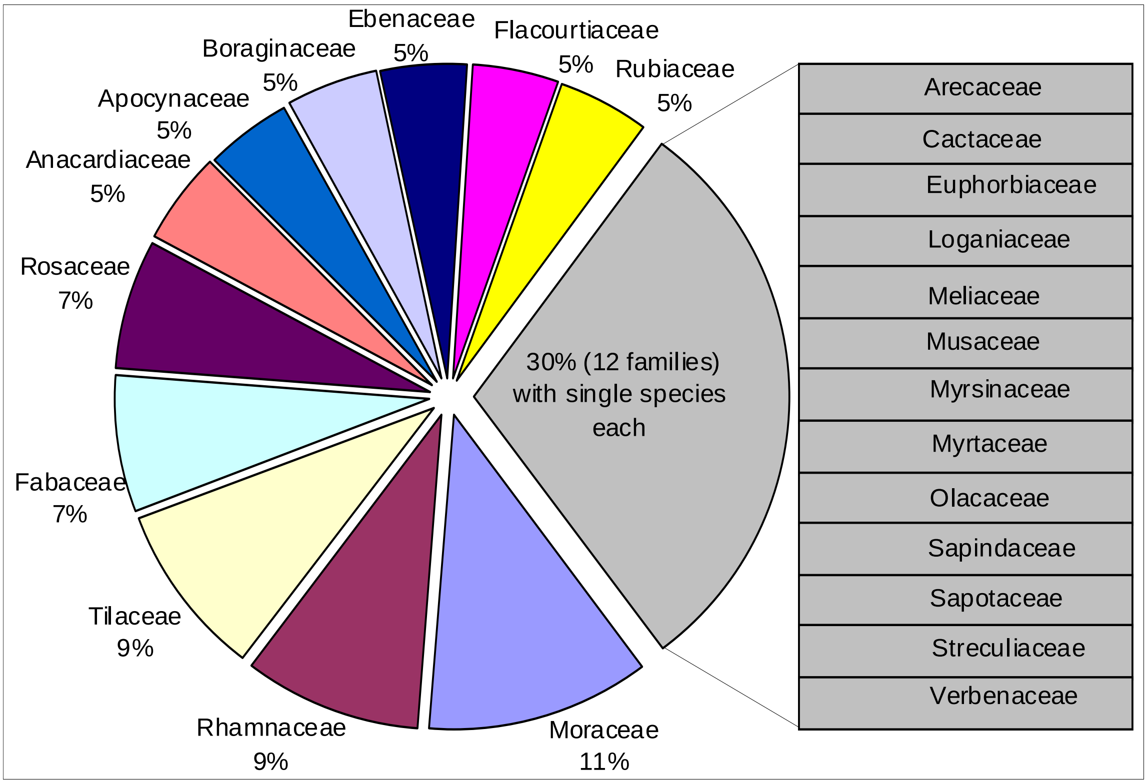


Figure 4.1: Wild fruit species distribution by family

With respect to life forms, most of the recorded species were trees (45.5%) while some 25% that includes, among others, *Euclea schmperi*, *Flueggea virosa,* most *Grewia* spp. and Rubus species occur as shrubs. Another quarter of the species occur opportunistically either as shrubs or trees. For instance, while *Ruhus* species, *Carissa* species, *R.abyssinica*, *V. madagascariensis* and most *Ziziphus* spp. often appear as shrubs, they also sometimes found as small or medium trees.

Some species as *R. abyssinica* are highly opportunistic in their growth forms. The later species is found in three forms depending on where and how it grows; in the open area (alone or in association with other plants) or in the forests. In Semen Mountains area where it grows its stems intertwined with *Erica arborea* L. and *Maytenus arbutfolia* Hochst. ex A. Rich., this species grows as a small tree. But when it grows alone in the open it appears a small shrub while in the forests it mostly occurs as a scrambling shrub. The study has additionally documented a palm (*Phoenix reclinata*) and a herb (*Ensete ventricosum*) species, which their fruits are edible. The herbaceous stem of the latter species is a staple food for millions of households in Southern Ethiopia while only its fruits are known edible in the study areas.

Wild fruit species appeared to occupy various habitats and ecological niches. Some species naturally inhabit forests and scrubs (*R.abyssinica, Rubus* spp*., Carissa* spp.*, D. abyssinica*) or often open forests and heaths (*Z.christi*). Typically, *X.americana, T. indica, Z.christi* and *Carissa* spp. frequent highly degraded sites. Other species like S*. guineense, M. kummel, D. mespiliformis, T.indica, Lepisanthes senegalensis* and some *Ficus* species are characteristically riparian. Some others as *F.virosa* frequent roadsides and disturbed areas. It was also noted that some species inhabit multiple niches. For instance, while they are dominantly riverine, *S. guineense* and *M. kummel* do also grow well elsewhere in farms, grazing lands and church compounds.

Seen at their spatial distribution, species like *S. guineense, M. kummel, Rubus* spp., *X. americana, D.abyssinica* and *Ficus* species are omnipresent and known far and wide in and outside the study areas. Others, as *D. mespiliformis, T. indica, Ziziphus* spp*., F.virosa, Oncoba spinosa* and *Strychnos* spp. are rather localized and less known to the general public other than in their growing milieu. This is primarily because of their limited agro-ecological distribution.

4.1.2 Species distribution by altitude and traditional agro-ecological zones

Wild edible fruit plants under study were found to occur at wide altitudinal ranges, where the majority was recorded in the low to mid altitude continuum. Accordingly, as shown in figure 4.2, barring the naturalized domesticated species, out of the total species recorded, 31, 38 and 7 species respectively occurred in the 1200-1500m, 1500-2300m and 2300-3300m altitudinal ranges. By and large, at altitudes of 3300m and above in the mountaintops *R. abyssinica* appeared to be prominent species. *Rubus steduneri* and *Dovyalis abyssinica* follow down at about 2800m and 2600m, respectively. Where the lowest point in the study area occurs, at about 1200m in the Blue Nile Gorge, *T. indica, X. americana, Z.mucronata* and *Grweia* species are very dominant.

Table 4.1 Lists of species recorded by life-form, ecological niche and agro - ecological zone

Table 4.1 Lists of species recorded by life-form, ecological niche and agro - ecological zone

Botanical Name	Family	Common / English name	Vernacular (Amharic) name	Life form	Habitat/Niche	Local ago-climatic zone
Acacia etbacia Schweinf	Fabaceae	Red thorn	Cheba, Dere, Ye-Eregna Kollo	tree	Low-mid altitude, forest, farm land, grazing land	Woinadega
Carissa edulis (Forsk.) Vahl	Apocynaceae	Simple-spined carissa	Agam	shrub/tree	Degraded montane forest and bushlands, woodlands, thickets, disturbed areas, riverine fringed vegetation	Woinadega, Dega
Carissa spinarum Linn.	Apocynaceae		Agam	shrub/tree	Degraded montane forest and bushlands, woodlands, thickets, disturbed areas, riverine fringed vegetation	Kola, Woinadega
Cordia africana Lam.	Boraginaceae	East African Cordia	Wanza	tree	Dry, moist and wet low to mid altitudes, homesteads, farm lands	Kola, Woinadega
Cordia ovalis R.Br.	Boraginaceae		Chewanza	shrub/tree	Riverine forest, valley bottoms & watercourses on rocky areas	Kola
Diospyros mespilliformis Hochst. Ex. A. D	Ebenaceae	African Ebony, Jackal-berry	Serkin, Marenta	tree	Mostly riverine forest, temporary streams, farms	Kola, Woinadega
Dovyalis abyssinica (A.Rich.) Warb.	Flacourtiaceae	Kei Apple	Koshim	shrub/tree	Upland rainforest, dry ever green forest, along hill escarpments	Woinadega, Dega
Ekebergia capensis Sparrm	Meliaceae		Lol	tree	Open grassland; dry, moist and wet climates	Woinadega
Ensete ventricosum (Welw.) Cheesman	Musaceae	False banana, Wild anana	Enset, koba, inbirbar, Infirfar, Guna Guna	herb	Upland forest edges, ravines and steep slopes, along streams , villages	Woinadega
Euclea schmperi Murr.	Ebenaceae		Dedeho	shrub	Dry woodland, bushland, riverine forest, marginal arid areas	Woinadega
Ficus sur Forssk. (F. Capensis)	Moraceae	Cape fig	Kodo, sholla, Klinto-sholla	tree	Along river banks, upland rain forest, mountain grassland or secondary shrub ; in farm lands	Kola, Woinadega
Ficus sycomorus L.	Moraceae	Wild fig, Bush fig	Bamba, sholla	tree	Riveine in dry areas, valleys, woodlands, grasslands, forest edges and clearings	Kola, Woinadega
Ficus thonningi Blume	Moraceae	Bark-cloth fig, common wild fig	Chibiha	tree	Farm lands, villages, open wood lands, town lanes, fences	Kola
Ficus vallis-choudae Delile	Moraceae	False cape fig	Bambulede, bambuleda	tree	Riverine forest or scrub	Kola, Woinadega
Ficus vasta Forrsk.	Moraceae		Warka	tree	On rocks, in forest clearings and riverine forest, forest margins, in public places, grazing lands	Kola, Woinadega
Flueggea virosa (Willd.) Vigot	Euphorbiaceae	snowberry tree	Ayihada, Bit	shrub	Open woodlands, riverine forests, forest edges, disturbed areas, farm lands, road sides	Kola, Woinadega
Gardenia ternifolia Schumach and Thonn	Rubiaceae		Gambilo	tree	Dryland forest, woodlands, forest edges, villages, grasslands	Kola, Woinadega
Grewia bicolor A. Juss.	Tiliaceae	False brandy bush	Somaya, sefa	shrub	River courses, degraded lands, grasslands	Kola
Grewia ferruginea Hochst.ex A. Rich.	Tiliaceae		Lenkuata	shrub/tree	Semi-arid woodlands,dry and moist mid- and lowlands, forest, along river courses	Kola, Woinadega
Grewia flavescens Juss.	Tiliaceae		betremuse, chirinchir	shrub	In sandy gravelly soils in river beds and streams	Kola
Grewia sp.	Tiliaceae		Sefa; ayat?	shrub	River beds and streams, rocky areas, acacia woodland	Kola, Woinadega
Lantana camara L.	Verbenaceae	Lantana, Red-flowered sage	Yeregna Qollo	shrub	By road sides, forest clearings, abondened fields,other disturbed areas	Woinadega
Lepisanthes senegalensis (Poir)Leenh.	Sapindaceae	Senegal cherry	Sel, Aberkeha, Aberkaka, Dingay-	tree	Mostly riveine forest	Kola, Woinadega

Table 4.1 Lists of species recorded by life-form, ecological niche and agro - ecological zone (continued)

Botanical Name	Family	Common / English name	Vernacular (Amharic) name	Life form	Habitat/Niche	Local ago-climatic zone
Mimusops kummel A. DC.	Sapotaceae		Ishe, Sheh, shiye, Kummel	tree	Riverine, forest fringes, dry ever green forests, wooded grassland, rocky hills, church forests	Kola, Woinadega
Myrsine africana L.	Myrsinaceae	African boxwood	Kechemo	shrub/tree	Hillsides in evergreen thickets, grasslands with forest remenants, edges of scrub in grassland and by rivers	Woinadega, Dega
Oncoba spinosa Forssk.	Flacourtiaceae	Snuff-box tree	Genfo, Dilih,Embobarya	tree	Mostly riverine forest	Kola, Woinadega
Opuntia ficus-indica (L.)Miller	Cactaceae	Indian fig	Beles, Kulkual	shrub	Road sides, stoney areas, villages	Kola, Woinadega
Phoenix reclinata Jacq.	Arecaceae	False date palm / Wild date palm	Selen, Zembaba	palm	Humid lowland woodlands, highland forests, swamps & rivers in dense clumps, ornamental in town lanes	Kola, Woinadega
Piliostigma thonningii (Schumach.) Milne-F	Fabaceae	Camel´s foot, Monkey bread	Dabja, yekolla-wanza	tree	Mid altitude open forests, forest edges	Kola, Woinadega
Rhus glutinosa A. Rich.	Anacardiaceae		Ashikamo,Embis, Shinet	tree	Rocky drylands, river valleys, decidious woodland and wooded grassland often in river valleys	Woinadega, Dega
Rhus vulgaris Meikle	Anacardiaceae		Kamo, Kamuna	shrub	semi-arid conditions, low and highland woodlands of moist to wet climate, road edges, forest	Kola, Woinadega
Rosa abyssinica Lindley.	Rosaceae	Abyssinian rose	Qega, Qaga	shrub/climber/creeper/tree	Upland dry evergreenforest, marigins of forest clearings, bushlands, grasslands, near habitations	Woinadega, Dega
Rubus apetalus Poir.	Rosaceae	wild raspberries	Enjori, Enzoria, Enzorye	shrub	Upland dry evergreen forest, marigins of forest clearings, bushlands, grasslands	Woinadega
Rubus steudneri Schweinf.	Rosaceae	wild raspberries	Enjori, Enzoria, Enzorye	shrub	Upland dry evergreen forest, marigins of forest clearings, bushlands, grasslands	Woinadega, Dega
Sterculia africana (Lour) Fiori	Streculiaceae		Darle	tree	Woodlands, bushlands in drylands	Kola, Woinadega
Strychnos innocua Del.	Loganiaceae	Monkey orange, wild orange	Tenkuhaye,Tenkubayo, Tenkuhayo	tree	Gravelly to stoney soil often rock slopes in dry areas	Kola, Woinadega
Syzygium guineense (Willd.)DC:	Myrtaceae	Water berry	Dokima, Leham	tree	Mostly riverine, deciduous woodland and rocky hills, moist and wet climate, churches	Kola, Woinadega,
Tamarindus indica L.	Fabaceae	Tamarind tree, Indian date	Roka, Humer, Semaytero	tree	River edges & banks, wooded grasslands, in farm lands and grazing lands	Kola
Vangueria madagascariensis J.F Gmel.	Rubiaceae		Embobarya, Masenko-barya, Guramaile	shrub/tree	Often riverine, semi-arid woodlands, hill edges, rocky slopes	Kola, Woinadega
Ximenia americana L.	Olacaceae	Wild plum, hog plum	Inkoy, Enkuaye, Kol	shrub/tree	Rocky outcrops in woodland; degraded sites	Kola, Woinadega
Ziziphus abyssinica Hochst. ex A. Rich	Rhamnaceae	Jujube	Abetere, Ametere	shrub/tree	Dry and moist woodlands and bushlands, forest edges, rocky slopes	Kola, Woinadega
Ziziphus mucronata Willd.	Rhamnaceae	Cape thorn, Buffalo thorn	Foch, Yeahia-qurqura	shrub/tree	River banks dry river beds, dry woodlands	Kola
Ziziphus species	Rhamnaceae	Jujube	Foch	shrub	Dry river beds, bushland,'villages,	Woinadega
Ziziphus spina-christi (L).Desf.	Rhamnaceae	Christ thorn, Jujube	Gava, Geba, Qurqura	tree	Bushland, open forests, farm lands,homegardens in semi-arids	Kola, Woinadega

Moreover, low and medium altitudes share 56.8% of the species and thus appear to have higher species similarity. On the other hand, species compositions of the higher altitudes tend to be quite dissimilar with both the low and medium altitudes which have respectively 2.3% and 15.9% of the species in common. A similar trend was observed in their agro-ecological distributions where a quarter of the species (24, 49%) fall in the *Kolla* and *Woinadega* zones (Figure 1.2).

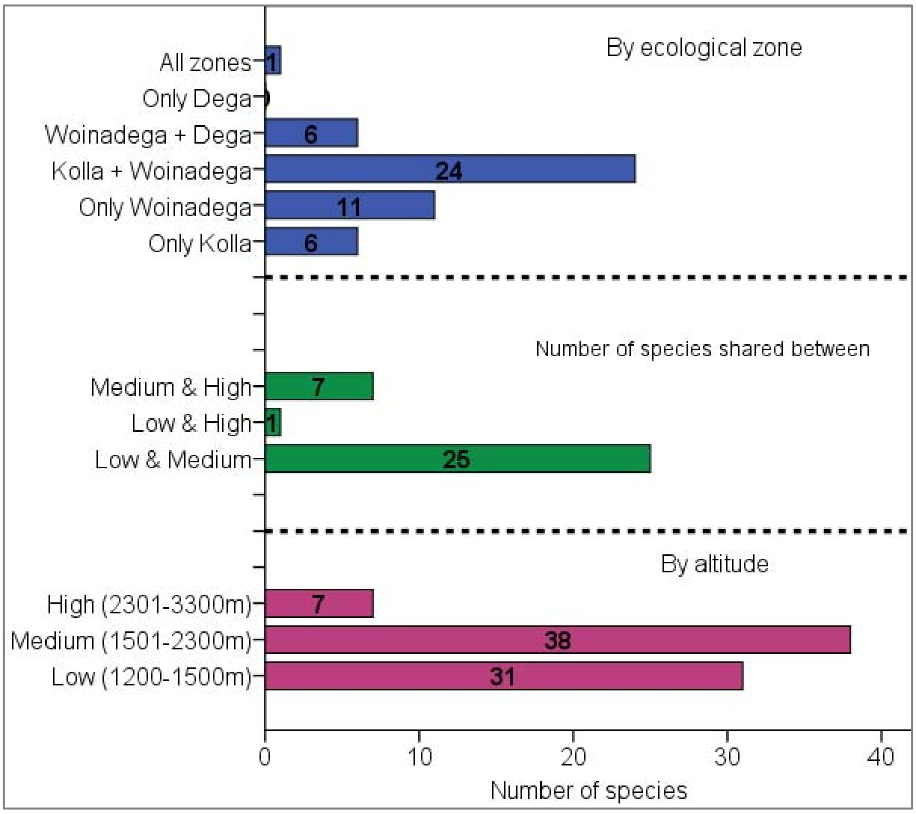


Figure 4.2: Species distribution by altitude and local agro-ecological zone, and the number of species shared between different altitudinal groups

4.1.3 Species richness and composition by site

As there are differences in species composition of the different altitudes so are between sites situated at different altitudes. Leaving aside the four domesticated species, Kurar houses the largest number of the total recorded species (28 species, 63.6%), followed closely by Bermariam (26, 59.1%) and Dibbahir (25, 56.8%). Similarly, Adiaregay contains 21 of the total species (47.7%) and Debir 10 (22.7%), Table 4.2. However, there is a great species overlap among the different sites.

Table 4.1: List of wild edible fruit bearing plant species recorded by site ("+" = present; "-" = absent)

Species	Debir	Dibbahir	Bermariam	Adiaregay	Kurar
Acacia etbacia Schweinf	-	-	-	-	+
Carissa edulis (Forsk.) Vahl	-	-	-	-	+
Carissa spinarum Linn.	+	+	+	+	-
Cordia africana Lam.	+	+	+	+	+
Cordia ovalis R.Br. Ex G. Don	-	-	-	-	+
Diospyros mespilliformis Hochst. Ex. A. DC.	-	+	+	+	-
Dovyalis abyssinica (A.Rich.) Warb.	+	+	+	-	-
Ekebergia capensis Sparrm	-	-	-	-	+
Ensete ventricosum (Welw.) Cheesman	-	+	-	-	+
Euclea schmperi Murr.	-	-	-	-	+
Ficus sur Forssk.	-	+	+	+	+
Ficus sycomorus L.	+	+	+	+	+
Ficus thonningi Blume	-	-	+	+	-
Ficus vallis-choudae Delile	-	+	+	+	+
Ficus vasta Forrsk.	+	+	+	+	+
Flueggea virosa (Willd.) Vigot	-	+	+	+	+
Gardenia ternifolia Schumach and Thonn	-	-	+	-	+
Grewia bicolor A. Juss.	-	-	-	-	+
Grewia ferruginea Hochst.ex A. Rich /*villosa*	-	+	+	-	+
Grewia flavescens Juss.	-	-	-	-	+
Grewia sp.	-	-	-	-	+
Lantana camara L.	-	-	-	-	+
Lepisanthes senegalensis (Poir)Leenh.	-	+	+	+	-
Mimusops kummel A. DC.	-	+	+	+	+
Myrsine africana L.	+	-	-	-	-
Oncoba spinosa Forssk.	-	-	+	-	-
Opuntia ficus-indica (L.)Miller	+	+	-	+	+
Phoenix reclinata Jacq.	-	+	+	-	-
Piliostigma thonningii (schumach.) Milne-Redh	-	-	+	-	-
Rhus glutinosa A. Rich.	-	-	-	-	+
Rhus vulgaris Meikle	-	+	+	+	-
Rosa abyssinica Lindley.	+	+	-	-	+
Rubus apetalus Poir.	-	-	-	-	+
Rubus steudneri Schweinf.	+	+	-	+	-
Sterculia africana (Lour) Fiori	-	-	+	-	-
Strychnos innocua Del.	-	+	+	+	-
Syzygium guineense (Willd.)DC.	+	+	+	+	-
Tamarindus indica L.	-	+	+	+	+
Vangueria madagascariensis Gmel.	-	+	+	+	+
Ximenia americana L.	-	+	+	+	+
Ziziphus abyssinica Hochst. ex A. Rich	-	+	+	+	-
Ziziphus mucronata Willd.	-	-	-	-	+
Ziziphus species	-	-	-	-	+
Ziziphus spina-christi (L).Desf.	-	+	+	+	-

Table 4.3 presents Sorenson distance and the absolute number of species shared between sites while figure 4.3 illustrates the resulting cluster diagram and ordination graph based on the Bray-Curtis average linkage method on a binary species data. Evidently, Adiaregay with Dibbahir (0.13) and Bermariam (0.19) recorded lower dissimilarity coefficient in the matrix and low cophenetic distance in the denderogram clueing a closer species composition in between these sites. Furthermore, Dibbahir with Bermariam (47.7%) and Adiaregay (45.5%) and Adiaregay with Bermariam (43.2%) appear to share greater proportions of the recorded species. Hence, taking 50% dissimilarity a cut-off point (Figure 1.3), Adiargay, Bermariam and Dibbahir can be regarded sites of closer species compositions. On the other hand, Kurar and Debir recorded the furthest distance (0.74) and shared the lowest number of species (5, 11.4%). As a result, the two sites are composed of quite different set of species compared to each other and to the rest of the sites.

Table 4.2: Sorenson distance and number of species shared between sites (agglomerative coefficient = 0.48)

Species	Distance				Number (percent) of species shared			
	Dibbahir	Bermariam	Adiaregay	Kurar	Dibbahir	Bermariam	Adiaregay	Kurar
Debir	0.49	0.67	0.55	0.74	9(20.5)	6(13.6)	7(15.9)	5(11.4)
Dibbahir	0	0.18	0.13	0.47	0	21(47.7)	20(45.5)	14(31.8)
Bermariam	*	0	0.19	0.56	*	0	19 (43.2)	12(27.3)
Adiaregay	*	*	0	0.55	*	*	0	11(25.0)

Further evidence was obtained from the ordination graph where the first two axes of the Principal Component Analysis explained much of the variance (the two Eigen values accounted for 80.7% of the total variance) and reinforced the clustering results (Figure 4.3). In this case again, Dibbahir, Adiaregay and Bermariam appear to be very closely situated in the fourth quadrant of the ordination graph while Debir and Kurar are located in the second and third quadrants, respectively. Moreover, species that appear dominant in respective sites tend to be distributed in the same quadrant where the sites are located. The three species that are shared among all sites appeared to lie at the origin of the ordination graph.

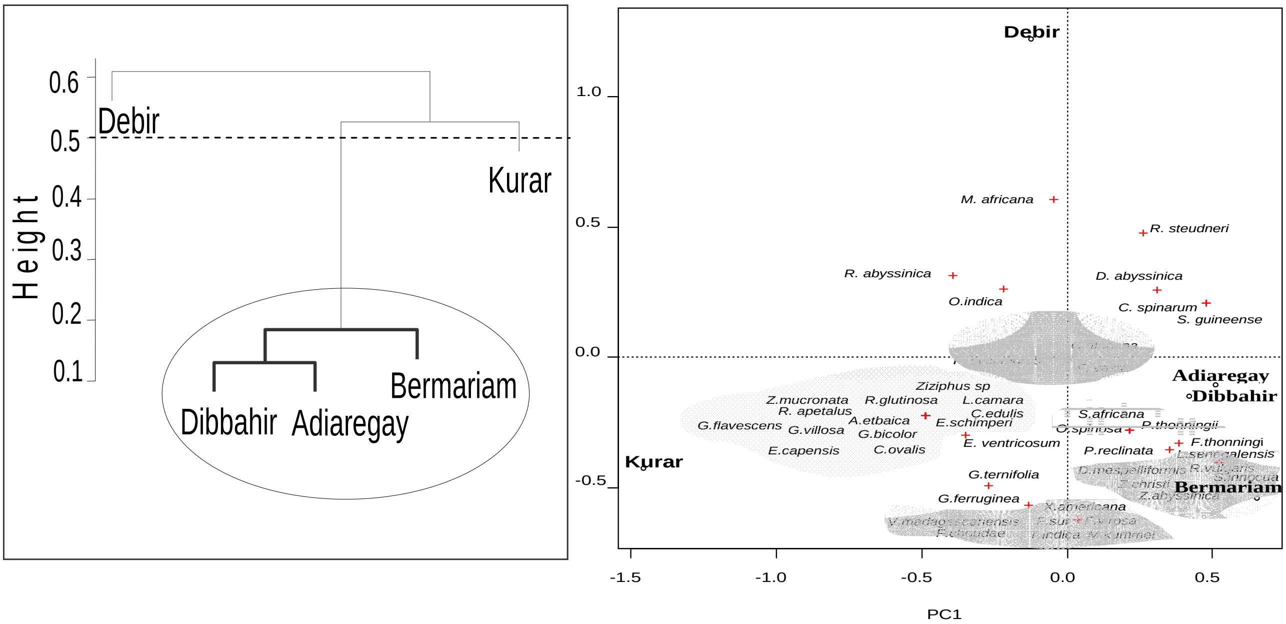


Figure 4.3: Clustering (left) and Principal Component Analysis (PCA) of sites and species (Cophenetic correlation, r = 0.94; P< 0.01)

4.2 Wild fruit species composition and diversity in the agricultural landscape

4.2.1 Species richness and abundance

Over the total study area, 74.5 % (n=90) of the informants possessed one or more wild fruit bearing plant species in their plots. Compared to the species recorded in the overall landscape, however, the species composition of the working landscape is relatively low that only 17 species were recorded. On a site basis, Bermariam recorded 10 (58.8%) of the 17 species closely followed by Adiaregay and Dibbahir at par (8, 47%), while Debir and Kurar recorded lowest number of species (3, 17.6%) each.

For the total study area, the mean number of species household $^{-1}$, density farm $^{-1}$ and site $^{-1}$ appeared to be 2.3, 2.6 and 1.6 in that order. On a site basis, Bermariam appears to be superior with all the above parameters while Debir recorded the lowest number of species. The lowest density farm $^{-1}$ and site $^{-1}$ was at Dibbahir (Table 4.4). The average pooled farm species richness when all farms of all sites are combined together is portrayed on species accumulation curves in figure 4.4. The 70 farms and 17 species are combined in the abscissa and ordinate, respectively.

Table 4.3: Mean wild fruit species richness, abundance and diversity

Site and number of samples (N)	Mean number of species farm^{-1} ($\pm$ SD)	Mean species abundance farm^{-1} ($\pm$ SD)	Tree density ($\pm$ SD)		Species density ($\pm$ SD)		Diversity Index		Mean landholding household^{-1} ($\pm$ SD)
			Mean density farm^{-1}	Mean density farm^{-1}site^{-1}	Mean density farm^{-1}	Mean density farm^{-1}site^{-1}	Shannon Diversity index	Evenness	
Adiaregay(N=16)	2.8± 1.17	19.1±16.14	16.6±15.6	9.6	3.1±3.19	1.4	1.46	0.54	1.98±1.56
Bermariam(N=18)	3.3±1.41	15.4±12.24	17.2±23.3	11.1	3.4±2.25	2.4	1.66	0.52	1.39±0.89
Debir(N=12)	1.3±0.45	3.3±2.50	5.3±3.7	4.4	2.3±1.80	1.5	0.31	0.46	0.76±0.44
Dibbahir(N=14)	1.6±0.93	6.7±4.61	5.1±3.0	3.9	1.5±1.25	1.0	0.98	0.33	1.73±1.50
Kurar(N=10)	1.6±0.50	3.7±2.50	4.0±1.9	3.8	2.0±0.93	1.6	0.80	0.74	0.98±0.58
All sites(N=70)	2.3±1.32	10.8±11.89	10.7±15.11	7.6	2.6±2.21	1.6	1.86	0.38	1.43±1.19

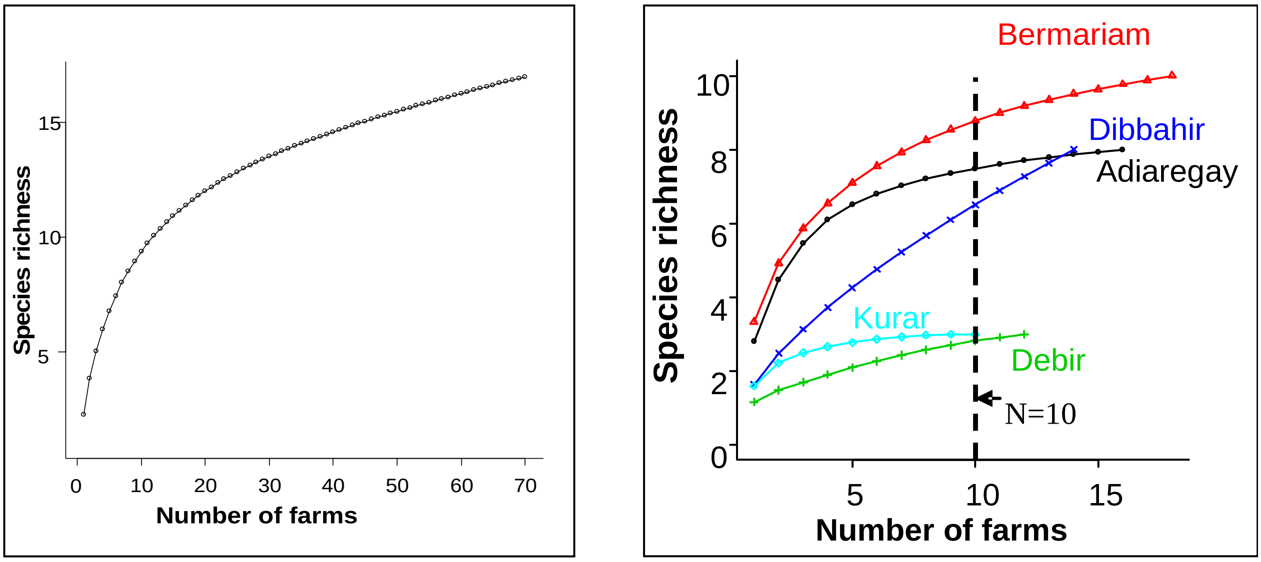
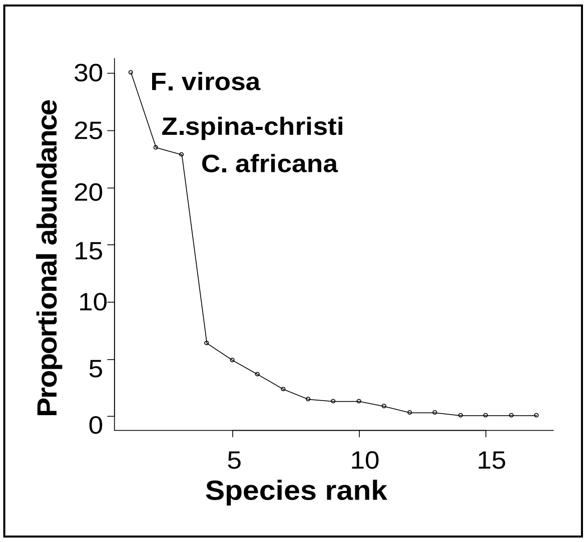


Figure 4.4: Exact sample-based species accumulation curve for the total farms (left) and individual sites (right)

Because new species are added with each new farm until all possible combinations of about ten farms (average pooled species richness of 9.3 ± 1.53 standard deviation), the species accumulation curve characteristically climbed steadily by one or more species. Afterwards, the curve leveled off as fewer species are added with each additional farm.

Likewise, looking into the accumulation pattern of individual sites in figure 4.4, Bermariam accumulates species more quickly and relatively steadily and thus has substantially higher species richness. Adiargay flattens off very quickly while at Dibbahir species accumulation is fast and even parallels Adiaregay after 13 farms. More importantly, by accounting for sample size differences species accumulation curves enabled to compare species richness of sites of unequal sample sizes at the same chosen sample size. For instance, at a sample size of ten where the Kurar site recorded the maximum species richness of three, Bermariam accumulated 8.8 species followed by Adiaregay (7.5), Dibbahir (6.5) and Debir (2.8). While this again confirms that Bermariam is relatively most species rich, it suggests that Adiaregay is not necessarily richer than Dibbahir and Kurar than Debir as the trend tends to change as more samples are considered.



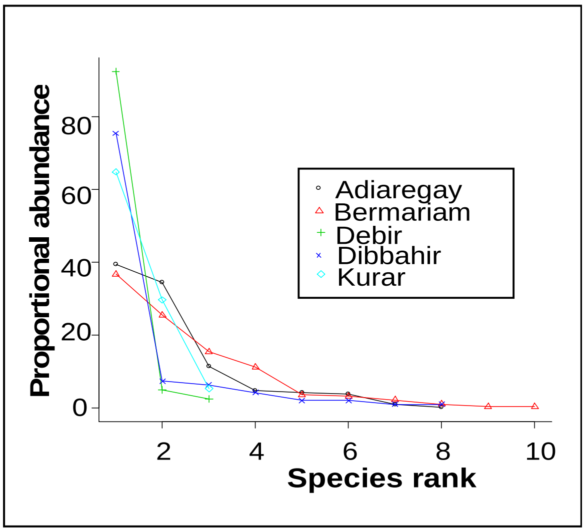


Figure 4.5: Rank-abundance curve of farm occurring wild fruit species for the study area (left) and individual sites (right)

Pertaining species abundance, the total number of trees of all species of all sites (N=70) was calculated at 754 with an average of 10.8 trees per household. The mean tree density farm $^{-1}$ and site $^{-1}$ was 10.7 and 7.6, respectively (Table 4.4). A lower figure with the later might mean that farms are unevenly stocked among households. Besides, species abundance differed by site as did the species richness. The highest and lowest relative abundances were recorded at Adiaregay (19.1 trees farm $^{-1}$) and Debir (3.3 trees farm $^{-1}$), respectively. But mean tree density per farm and site was highest at Bermariam. This suggests that despite their large sizes, farms at Adiaregay are inadequately stocked. Kurar recorded both the lowest number of trees farm $^{-1}$ and site $^{-1}$.

Nevertheless, as the rank-abundance distribution curve in figure 4.5 illustrates, only a few tree species occur in greater abundances in the working landscape. This is clearly shown by the steepness of the curve that sharply declines after a few species. Generally, *F. virosa*, *Z. spina-christi* and *C. africana* are the most abundant species accounting for 30.1%, 23.5% and 22.9% of the total number of trees of farm recorded fruit bearing species in that order (Table 4.5). Species that lie down at the right lower extreme of the curve (like *X. americana, O. ficus-indica*, *Z.abyssinica* and *V. madagascariensis*) occur at very low abundances and thus have low level of farm integration. Likewise, as evidenced from the rank-abundance distribution curves of separate sites Bermariam and Adiaregay are relatively species rich (as shown by the greater breadth curve) and trees tend to be evenly distributed among several species. Conversely, Debir, Dibbahir and Kurar are dominated by one or a few species.

Table 4.4: Relative abundance of wild fruit species in agricultural landscapes and mean species abundance by site

Species	Species Ranking		Mean species abundance per farm				
	Abundance	Proportion	Adiaregay (n=16)	Bermariam (n=18)	Debir (n=12)	Dibbahir (n=14)	Kurar (n=7)
Flueggea virosa (Roxb. ex Willd.)	227	30.1	7.60	5.70	0.00	0.30	0.00
Ziziphus spina-christi (L.) Desf	177	23.5	6.60	3.90	0.00	0.00	0.00
Cordia africana Lam.	173	22.9	2.20	2.40	0.00	5.10	2.40
Ficus species	48	6.4	0.80	1.70	0.00	0.10	0.20
Rosa abyssinica R. Br.	37	4.9	0.00	0.00	3.10	0.00	0.00
Carissa species	28	3.7	0.80	0.60	0.00	0.40	0.00
Diospyros mespiliformis Hochst. ex A.	18	2.4	0.90	0.20	0.00	0.00	0.00
Tamarindus indica L.	11	1.5	0.00	0.00	0.00	0.00	1.10
Ficus thonningii Blume	10	1.3	0.10	0.50	0.00	0.00	0.00
Rhus species	10	1.3	0.20	0.30	0.00	0.10	0.00
Syzygium guineense (Willd.) DC.	7	0.9	0.00	0.00	0.00	0.50	0.00
Dovyalis abyssinica (A. Rich.) Warb.	2	0.3	0.00	0.00	0.20	0.00	0.00
Phoenix reclinata Jacq.	2	0.3	0.00	0.00	0.00	0.10	0.00
Ximenia americana L	1	0.1	0.00	0.10	0.00	0.00	0.00
Opuntia ficus-indica (L.) Mill.	1	0.1	0.00	0.00	0.10	0.00	0.00
Ziziphus abyssinica Hochst. ex A.	1	0.1	0.00	0.10	0.00	0.00	0.00
Vangueria madagascariensis J.F.	1	0.1	0.00	0.00	0.00	0.10	0.00

4.2.2 Species diversity and pattern

The Shannon diversity index for the entire study area was calculated at 1.86 (Table 4.4) which is about 65.7% of the maximum possible value that would have been obtained had all species occurred at equal frequency (2.83) which suggests a moderate level of diversity. At site level, Bermariam recorded a relatively higher species diversity (1.66) followed by Adiaregay (1.46) while Debir recorded least (0.31). This was further elucidated in figure 4.6 by the Rényi diversity profiles. Bermariam and Adiaregay sites in that order have a higher species richness as well as diversity while Debir is again least in both parameters. Nevertheless, although the Shannon diversity index shows Dibbahir is more diverse to Kurar the diversity profiles show that this is not the case. This is because though Dibbahir has higher species richness its species are less evenly distributed than Debir. Hence, it is not possible to order these two sites by diversity as their profiles are intersecting.

In addition, diversity profiles gave an insight into evenness of sites. As evidenced from the anti-logarithm of the reciprocal profile value at α = ∞, the proportion of the most abundant species is 43.2%, 38.2%, 92.8%, 76.0% and 64.9% respectively for Adiaregay, Bermariam, Debir, Dibbahir and Kurar sites. A lower proportion of the most abundant species translates to a higher evenness that corresponds to profiles with high α = ∞ value. Apparently, Bermariam and Adiaregay tend to be relatively even while Debir is uneven, which is also clearly seen by the position of respective profiles.

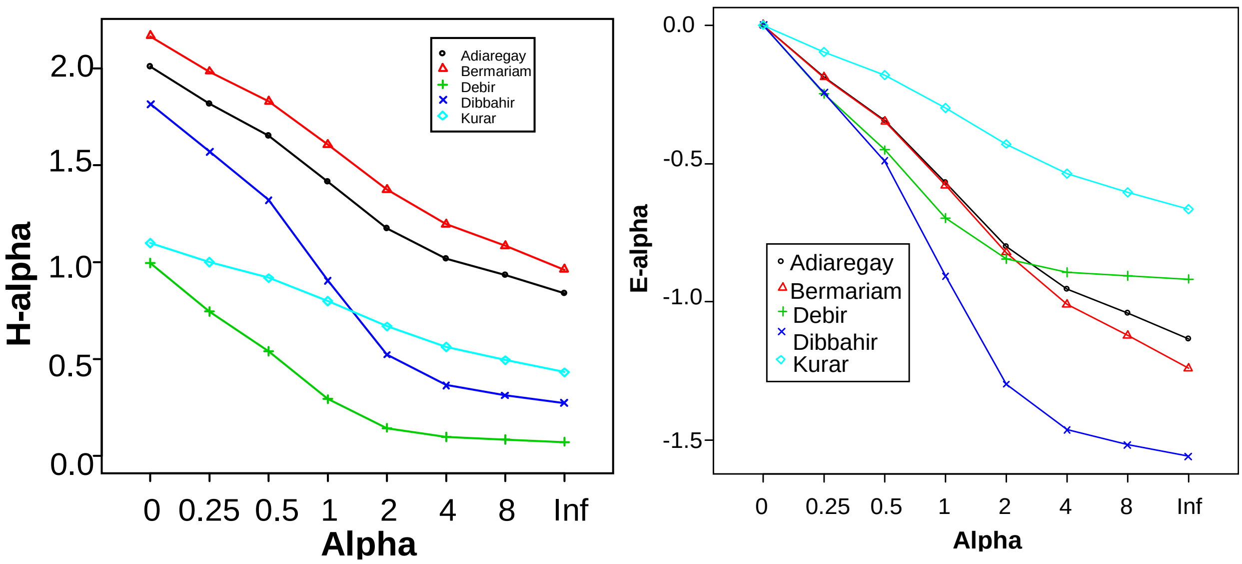


Figure 4.6: Rényi species diversity (left) and evenness (right) profiles for sites based on 100 randomizations

Rényi Evenness profiles in figure 4.6 further compare evenness of sites on a more direct way but in this case regardless of species richness. Evidently, by having a profile that is consistently above all other profiles Kurar appears relatively species even. On the contrary, Dibbahir appears uneven for its low positioned profile. Moreover, evenness values at E_∞ provide an insight into the evenness of dominant species while the ratio of E_1 to E_∞ hints the evenness pattern about the rest of the species (Kindt 2002). Accordingly, the dominant species is evenly distributed at kurar followed by Debir, moderately at Adiaregay and Bermariam and unevenly at Dibbahir. The intersection of evenness profiles at Debir and Bermariam indicates that the dominant species is evenly distributed with the former but not with the latter. The other species (other than the dominant) are evenly distributed at Kurar followed by Bermariam, moderately at Adiaregay and Dibbahir and less evenly at Debir.

4.2.3 Species diversity and ethno-ecological importance of agricultural niches

Comparison of the different niches of the working landscape for species occurrence revealed that the average species richness declines in the order of farm edges (12 species), grazing and uncultivated lands (11), farmlands (10) and homesteads (8), Figure 4.7. Compared to farmlands and grazing lands, homesteads are also less diverse. In terms of evenness, farmlands tend to be even (0.55) while the farm edges are less even (0.43). Table 4.6 furnishes the ethno-ecological importance values of the different niches. Interestingly, farm edges (1.49) followed by homesteads (1.03), grazing areas (1.00) and farms (0.57) appear to be ethno-ecologically important, that is, they are important sources of wild fruit bearing species to the people. Species-wise, farmlands and homesteads are dominated by *Z.christi* and *C. africana*. All the way, *V.madagascariensis*, *Z.abyssinica* and *X.americana* were encountered only in uncultivated or grazing lands while *F. virosa* and Rhus species were most frequent in farm edges.

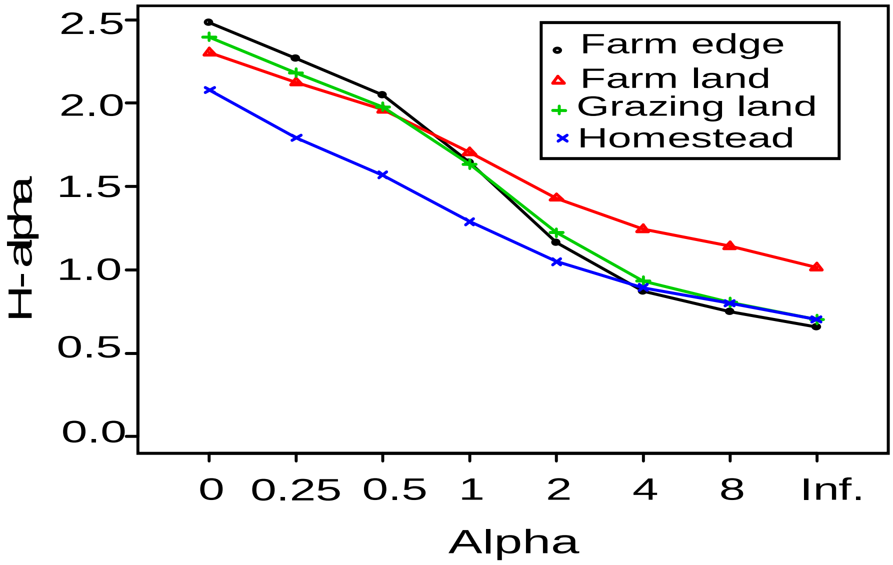


Figure 4.7: Rényi species diversity profiles for the different niches (100 randomizations)

A closer look at the mode of integration of some of the major species in the working landscapes showed that *C. africana* is integrated with maize, tef, (*Eragrostis abyssinica* L.), finger millet, sorghum, niger seed, etc. in the farmlands while it is grown as hedge or coffee shade in homesteads. *Z. spina-christi* is common as an intercrop with tef, sorghum and niger seed or as live fence or border-demarcating tree. In homesteads, this species usually appears as a fence or hedge around the houses. In farms, *T. indica* is usually left in sorghum, tef, sesame, etc. fields while its growing is avoided in homesteads for some unfounded beliefs. *R. abyssinica* is used as a live fence around the houses and homesteads especially in the Debir area.

Table 4.5: Comparison of the ethno-ecological importance value of the different niches of the agricultural settings as a source of wild fruit bearing plant species

Species	Salience	Proportional abundance				Salience X abundance			
		Farmland	Homestead	Farm edge	Grazing/ uncultivated land				
	a	b	c	d	e	a X b	a X c	a X d	a X e
Cordia africana Lam.	0.51	0.18	0.65	0.14	0.02	0.09	0.33	0.07	0.01
Ficus species	0.43	0.19	0.21	0.42	0.19	0.08	0.09	0.18	0.08
Diospyros mespiliformis Hochst. ex A.	0.27	0.00	0.56	0.22	0.22	0.00	0.15	0.06	0.06
Ziziphus spina-christi (L.) Desf	0.40	0.23	0.38	0.31	0.08	0.09	0.15	0.12	0.03
Flueggea virosa (Roxb. ex Willd.)	0.26	0.06	0.00	0.72	0.22	0.02	0.00	0.19	0.06
Rhus species	0.17	0.00	0.00	0.80	0.20	0.00	0.00	0.14	0.03
Carissa species	0.56	0.11	0.00	0.43	0.46	0.06	0.00	0.24	0.26
Ficus thonningii Blume	0.06	0.20	0.10	0.60	0.10	0.01	0.01	0.03	0.01
Ziziphus abyssinica Hochst. ex A.	0.04	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.04
Ximenia americana L	0.29	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.29
Rosa abyssinica R. Br.	0.33	0.08	0.62	0.30	0.00	0.03	0.21	0.10	0.00
Syzygium guineense (Willd.) DC.	0.28	0.14	0.00	0.86	0.00	0.04	0.00	0.24	0.00
Phoenix reclinata Jacq.	0.06	0.00	0.00	1.00	0.00	0.00	0.00	0.06	0.00
Vangueria madagascariensis J.F.	0.12	0.00	0.00	0.00	1.00	0.00	0.00	0.00	0.12
Dovyalis abyssinica (A. Rich.) Warb.	0.12	0.50	0.50	0.00	0.00	0.06	0.06	0.00	0.00
Opuntia ficus-indica (L.) Mill.	0.03	0.00	1.00	0.00	0.00	0.00	0.03	0.00	0.00
Tamarindus indica L.	0.14	0.64	0.00	0.36	0.00	0.09	0.00	0.05	0.00
Total ethno-ecological importance value						**0.57**	**1.03**	**1.49**	**1.00**

4.2.4 Relative species frequency

The study revealed that despite the occurrence of several species in the working landscapes, only a few of them occur at a relatively higher frequency. As portrayed in figure 4.8 (not all species are indicated), *C.africana* (26.6%) and *Z.christi* (14.6%) appear to be species of higher relative frequency that occurred in 60 and 33 of the 70 farms, respectively. Site-wise, as is evident in figure 4.9, *C.africana* is highly frequent at Bermariam, Dibbahir and Kurar sites and is second only to *Z.spina-christi* at Adiaregay. At Debir, *C.africana* is totally missing due to climatic restrictions, rather *R.abyssinica* is highly frequent. At Adiaregay, most farmers possess *Z.spina-christi*, followed by *C.africana* and *F.virosa* at par while at Dibbahir 50% of sample farms possess *C.africana* followed by *S.guineense* (16%). Likewise, half of the farms at Kurar composed of *C.africana.*

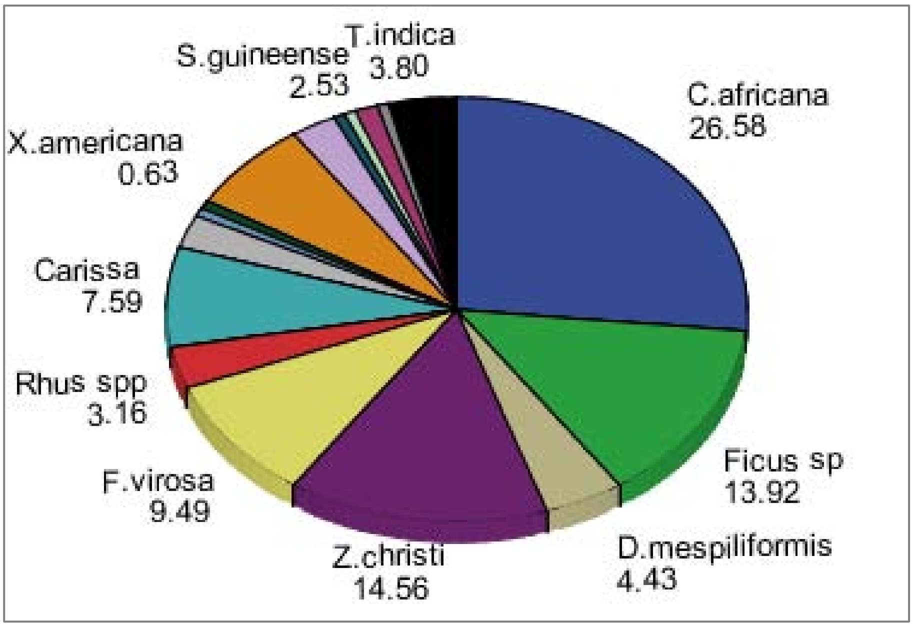


Figure 4.8: Relative frequency (%) of edible fruit bearing species in agricultural settings

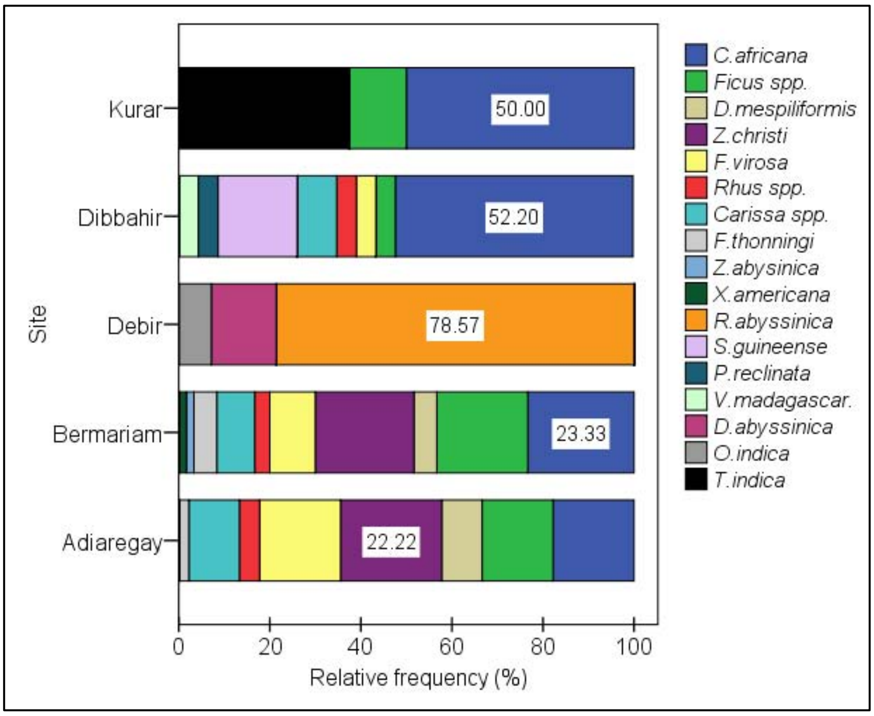


Figure 4.9: Relative frequency of species in farms by site (numbers inside the bars designate the value for most frequent species)

4.2.5 Factors affecting species occurrence and diversity in agricultural landscapes

4.2.5.1 Determinants of farm occurrence

For some 30% of 92 informants, growing fruit bearing species in farms is not appealing for one or more reasons. As shown in figure 4.10, their free availability in the natural environment (28.5%), undermining their value as a fruit (22.9%) and simply ignorance (19.6%) were the most frequent answers. Also, land and labor shortage, establishment problem, stigmas on their use, climatic limitations, ecological niche differences as well as comparative advantage of staple crops were reported. Raised emphatically in group discussions was also incompatibility with annual crops about which most respondents (70.7%) accounted it mainly for shading and space competition. Lack of encouraging market, seedling unavailability, theft cutting (e.g. *C. africana*), thorniness (like in *Z.christi*) which makes farming operations arduous to both human and oxen, luring ants (e.g. *C. africana*) and prejudices of sheltering bad spirits (*T. indica*) were additionally reported to hinder the domestication efforts. In a few cases, wild fruits were reported to lure and provide a haven for birds for building roosts that attack associated crops.

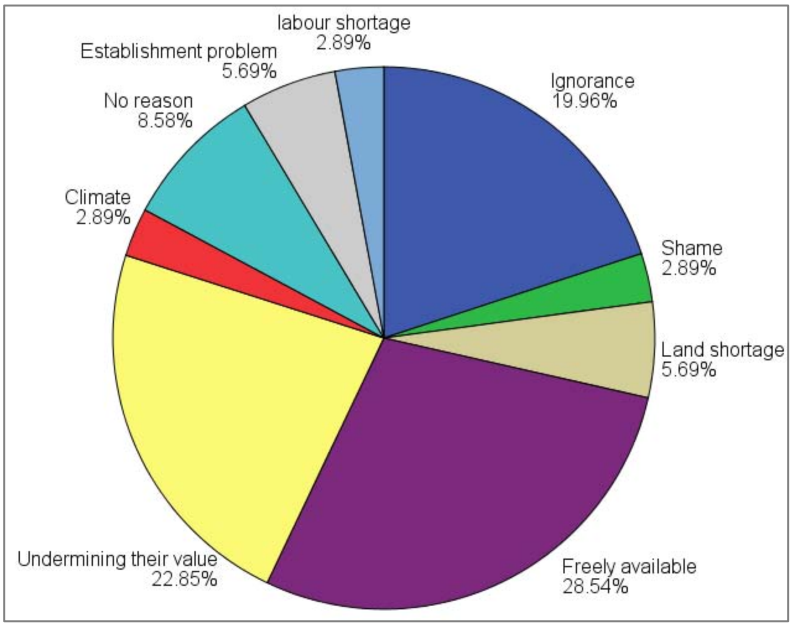


Figure 4.10: Reasons for not domesticating wild fruit bearing plant species (N=35)

Exploration into possible relationships between some household and bio-physical factors and propensity of retaining fruit trees on farms revealed that literacy, extension contact, land size and responsibility in the community bear significant influences (Table 4.7). Except with extension contact, directions of these relationships are positive. Literate households show greater tendency to have edible fruit bearing species in their farms than illiterate ones. Households with larger plots tend to have trees than those with smaller plots. Despite statistically weak, there is also an indication that gender and land ownership pose some influence on wild fruit tree farm inclusion. Among physical factors, slope and altitude appeared to have positive and negative influences, respectively.

Table 4.6: Factors affecting farm inclusion of wild fruits (quasi-binomial variance GLM with a logit link)

Parameters	Df	Deviance	Pr(F)
<none>		56.510	
Age	1	57.227	0.345
Gender	1	59.297	0.065 .
Education	1	59.938	0.041 *
Children	1	57.302	0.321
Land ownership	1	59.333	0.063 .
Land size	1	63.512	0.004 **
House type	1	56.516	0.931
Religion	1	58.657	0.104
Main job	1	56.550	0.823
Off-farm job	1	58.570	0.112
Livestock	1	56.668	0.657
Extension	1	62.930	0.005 **
Responsibility	1	64.171	0.002 **
Altitude	1	62.804	0.006 **
Slope	1	60.626	0.025 *

Significance: '**' 0.01; '*' 0.05; '.' 0.1; Dispersion parameter = 0.73; Deviance explained: 38.12%

4.2.5.2 Determinants of species richness and diversity

As shown in table 4.8, the number of species (F=12.29, P<0.001) and trees (F=27.93, P<0.001) are highly influenced by the altitude where the farms are situated. This relationship is negative that as one goes to a higher altitude farms, both the number of species and trees decreases progressively. Similarly, land size bore a significant positive influence on the abundance of fruit trees on farm (F=10.88, P<0.001), where the household's landholding increases there is a probability of having more number of trees. However, the overall poor correlation between species richness and abundance with most socio-economic and physical variables and the low deviance of the model might mean that the relationship is probably non-linear and highly complex. It might also be that other unconsidered factors are responsible for the same.

Table 4.7: Effects of household attributes and physical factors on farm species richness and abundance of wild fruit species

Parameters	Species richness	Species abundance
Age	NS	NS
Gender	NS	NS
Education	NS	NS
Number of children	NS	NS
Land size	NS	*
Altitude	***	***
Slope	NS	NS
Method used	Poisson GLM, log link	Negative Binomial GLM, log link
Dispersion parameter	1	2.32
Deviance explained	37.28%	39.06%

Significance codes: ***' = 0.001; '*' = 0.05; 'NS' = not-significant

4.3 Cultural domain of wild edible fruits and associated local knowledge

4.3.1 Cultural domain

In the free-listing exercise, respondents volunteered altogether the names of more than 50 species across the study areas (N=104). On average, each informant listed 9.6 species that ranged from as low as three to a maximum of 23 (Figure 4.11). After excluding species of single informant frequency, 46 species were retained to constitute the wild fruits domain of the entire study area. The reason for leaving out rare species is that it is only species that are in active use are expected to be listed with a high frequency while the low-frequency terms means they are either in passive use or are used only in some idiolects. Besides, both cultural domains as well as informants' competence varied by District and site (Table 4.11). Accordingly, Debark and Adiarkay district domains comprised of 23 and 26 species, respectively. At site level, Kurar and Debir recorded respectively the longest and shortest list with 28 and 11 species in their domains.

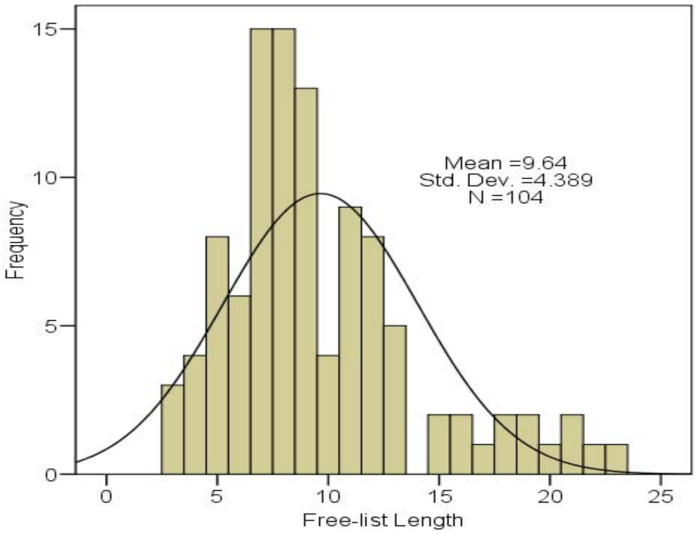


Figure 4.11: Free - list frequencies of wild fruits across study areas (N=104)

Among the personal attributes hypothesized to influence informants' familiarity or knowledge of edible species using free-list length a proxy, the age of informants appeared to have a highly significant negative influence (Table 4.9). Those informants at and under the median age of 40 appeared to be more knowledgeable to those above. This was clearly demonstrated by the contingency table where age has a significant association with free-list length (Pearson χ^2 =13.5; P<0.01), Table 4.10. While 43.6% of the median age and lower listed 10 or more species (about mean value), the corresponding figure for those above median age was only 8.1%.

Table 4.8: Relationships between informant attributes and free-listing length
Negative binomial GLM (free-list ~ age + education + language + religion + gender, link = log)

Parameters	Estimate	Std. Error	Pr(>|z|)
Intercept	2.589	0.245	< 2e-16 ***
Age	-0.012	0.003	0.000 ***
Education	-0.083	0.083	0.319
Gender	0.080	0.103	0.437
Language	-0.010	0.083	0.903
Religion	0.079	0.133	0.552

'***' = significant at P<0.001; Dispersion parameter = 33.3; Deviance explained: 16.7%

Table 4.9: A 2 X 2 contingency table on the associations of age and free - list length

		Age of the informant (years)			
		Count & % within age	≤ 40	> 40	Total
Free-list length	≤ 10	Count	31	34	65
		%	56.4	91.9	70.7
	> 10	Count	24	3	27
		%	43.6	8.1	29.3
	Total	Count	55	37	92
		%	100	100	100

Significant at Pearson $\chi 2$ (13.5) = P<0.01); S.E = 0.08

4.3.2 Comparison among the free-lists of the different sites

The dendrogram in figure 4.12 demonstrates free-list similarities and differences among informants' of the different sites. Taking 10.5% dissimilarity coefficient a cut-off point, Adiaregay, Bermariam and Dibbahir informants by and large appeared to have similar species in their free-lists and are thus clustered under one category. On the other hand, Debir and Kurar informants tend to have quite dissimilar species in their free-lists. This result is well comparable to the species composition similarity of sites under section 4.1.3.

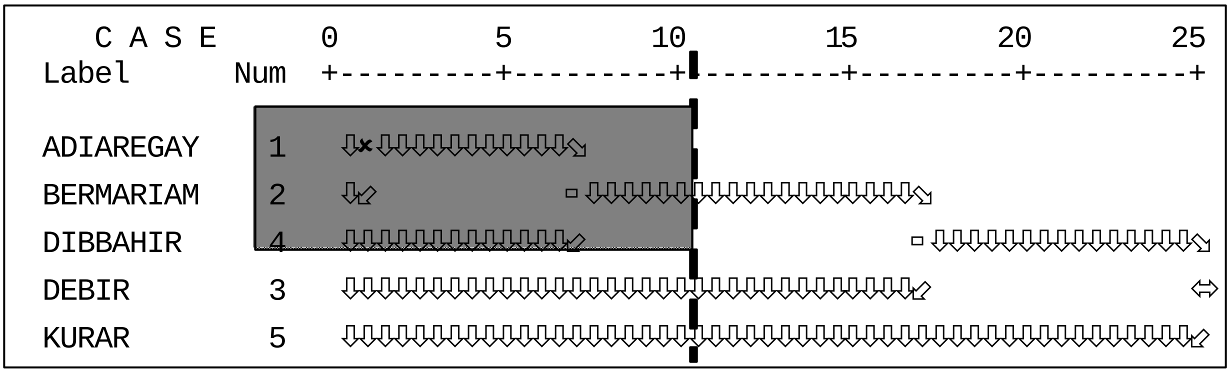


Figure 4.12: Classification of informants of different sites based on free - list similarities (Bray-

Curtis average linkage method)

4.3.3 Species saliency

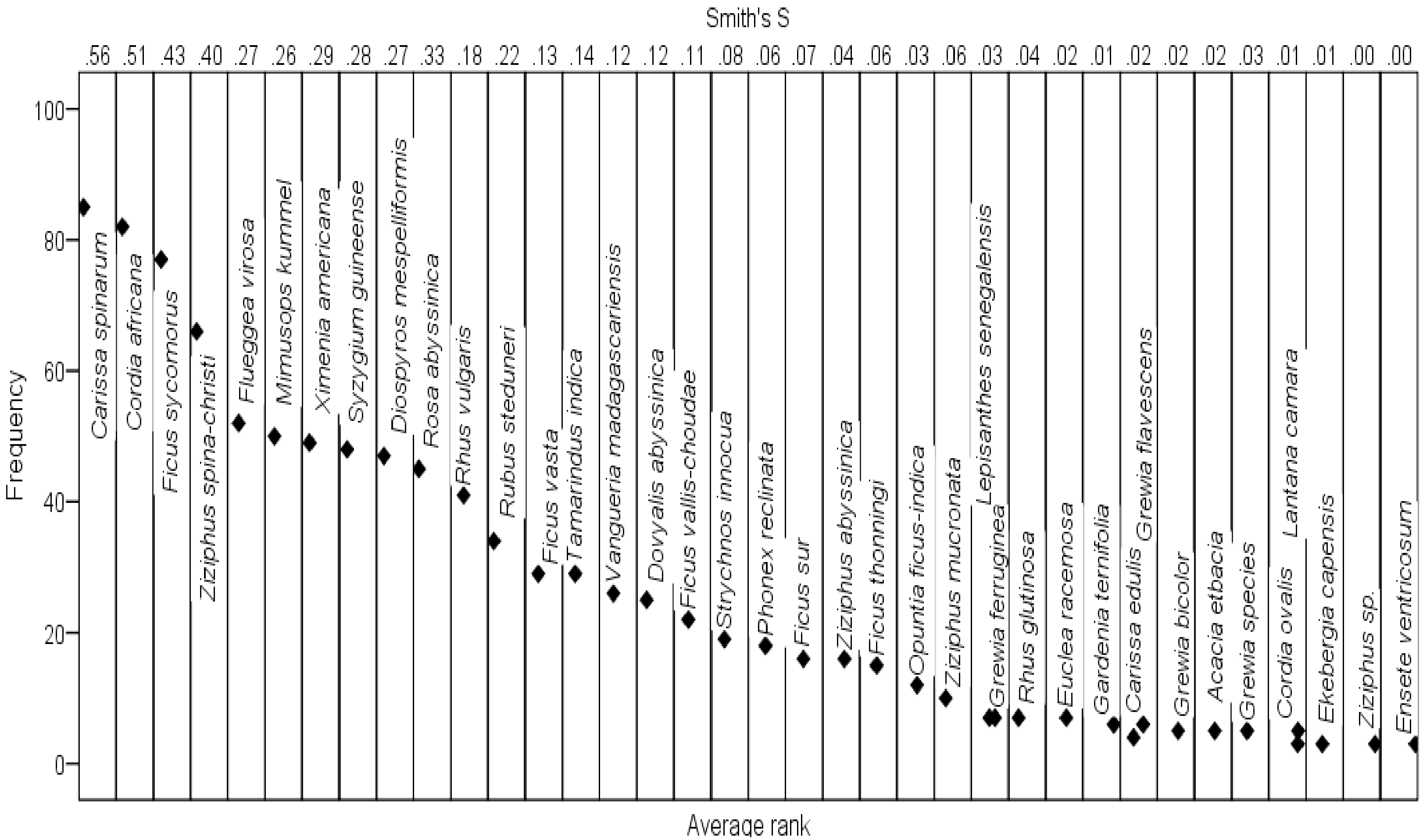
Figure 4.13 illustrates a plot of the average rank by frequency of mention and Smith's Saliency Index value of species mentioned by three or more informants during free-list exercises. A salient species is one with high frequency of mention by informants and appearing early in their listing which also corresponds to a higher Smith's (S) saliency Index. Accordingly, among several others, C*. spinarum, C. africana, F.sycomorus* and *Z.christi* are the most frequent species with informant frequency level of 85, 82, 77 and 66% in that order, as well as, higher rank and Saliency Index. Hence, these species can be regarded the most significant to the informants.

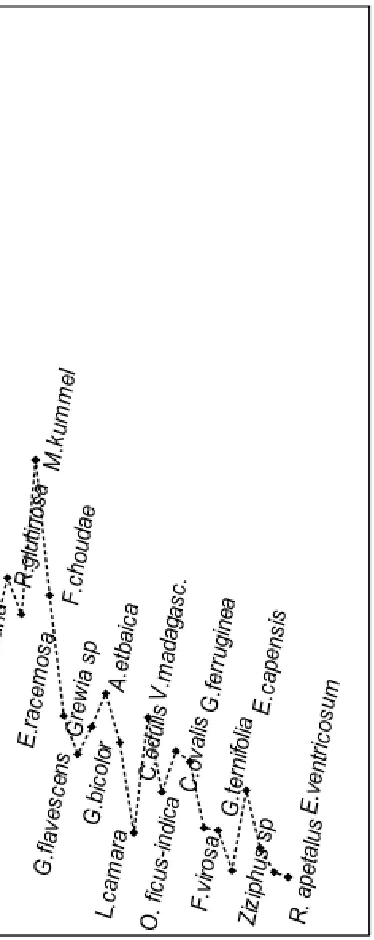
A closer look at the Smith's Saliency index score for individual sites domain (Figure 4.13) discloses that the pattern is generally the same, where in all instances the curve descends from more towards less salient species. Nevertheless, slight variations are noticeable among sites with respect to the number and types of salient species. Apparently, the most salient species appeared to record highest score at Debir (*R.abyssinica*, 0.98) and lowest at Bermariam (*Z.christi*, 0.70). Another difference evident from the figure was the cut-off point of the curves. While the curve suddenly falls sharply after only two species at Adiaregay, it descended after about three species at Dibbahir and Kurar. In extreme cases, the curve flattens off sharply and progressively just only after one species at Debir while at Bermariam the curve elbowed after about six species. The later substantiates why the value of salience index for the most salient species is higher at Debir than at Bermariam. *C.spinarum* and *Z. christi* appears to be among the top salient species at Adiaregay, Bermariam and Dibbahir sites. But the most salient species tend to be peculiar at Debir (*R.abyssinica* and *R.stenueri*) and Kurar (*T. indica, X.americana* and *Z.mucronata*).

Furthermore, the saliency level of species was noted to slightly change by the scale of cultural domain analysis: study area, district and site. For instance, while *R. abyssinica* was the most salient species at the district level in Debark, it scored medium saliency index at study area level. Similarly, while it was most salient at Dibbahir site the saliency of *S. guineense* was much underestimated at the district level. However, scale of analysis did not have significant influence on saliency for species like *C. spinarum* that have wider distribution and familiarity across sites.

Figure 4.13: Average rank by frequency and Smith's S Index plot for 39 wild fruit species

Figure 4.14: Pattern of Smith's S index for different species of the five study sites





4.3.4 Species co-occurrence and association in free-lists

As shown in figure 4.15, a non-metric two-dimensional scaling map of wild fruits domain of Debark district yielded a clear insight into the relationships among the species as well as their level of importance. As is evident on the map, species appeared more or less in what is commonly termed as fried egg fashion. The most salient species of the domain clustered in the inner core, the less frequent and less important species in the second circle and species mentioned rarely in the outermost circle. Consequently, the innermost circle of the map composed of 16 species which includes, among others, *R. abyssinica, C. spiarum, Rubus* and *C. africana*. Particularly, *R. abyssinica* and *R. steudneri* (clustered in the first iteration at 0.82 similarities in the tree diagram, not shown) and *C. africana* and *F.sycomorus* (second iteration at 0.79% similarities) appeared to be species that are most frequent and consistently mentioned together. Next, the middle circle is occupied by five species; namely, *F. vasta*, *F. vallis-choudae*, *M.africana,* Opuntia and *Z. abyssinica*. These groups of species are less important and regarded delicacies of children. The outermost circle consists of two outlier species (*C. arabica* and *C.aurantium*) that were mentioned by two informants each.

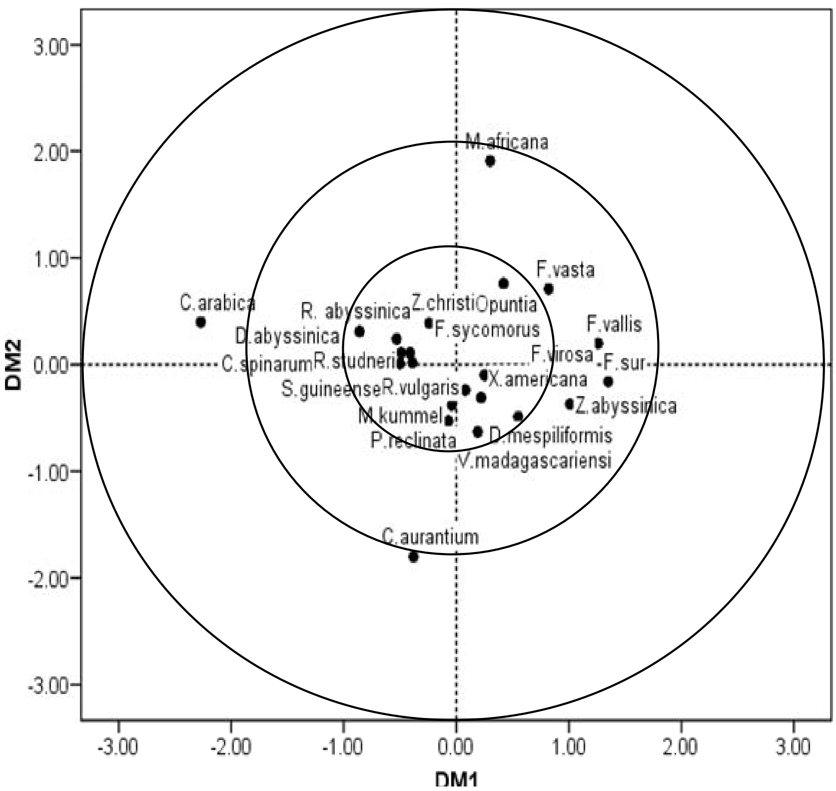


Figure 4.15: A non-metric two-dimensional scaling map (NMDS) of wild fruits species domain at

Debark (Stress in 2 dimensions = 0.99)

Moreover, an interesting pattern was emerged in the NMDS map that species mentioned by informants of the two sampling sites of the district are clearly differentiated in space. Accordingly, most species in the second quadrant are those listed by Debir informants while those in the third and fourth quadrant came from Dibbahir informants.

The tendency of grouping of fruit species was further illustrated through cluster analysis. At District level, clustering of species was demonstrated by a cluster diagram of Adiarkay as an example (Figure 4.16). In this case, at a cut-off point of 10.5% dissimilarity coefficient two clusters are apparent. The larger cluster consists of seven species: *C. spinarum, Z. spina-christi, C. africana, F. sycomorus, D. mespiliformis, F.virosa* and *R.vulgaris*. This list perfectly corresponds to the most salient species of the district's domain. Out of these, by being joined in the second iteration (0.14 dissimilarity coefficient), *C. spinarum* and *Z. spina-christi* tend to be frequently mentioned together. A second cluster was formed out of two infrequently mentioned species, *P.thonningi* and *G.ferruguinea* that were again consistently mentioned together.

Figure 4.16: Clustering of species in Adiarkay district free - lists (Bray - Curtis average linkage)

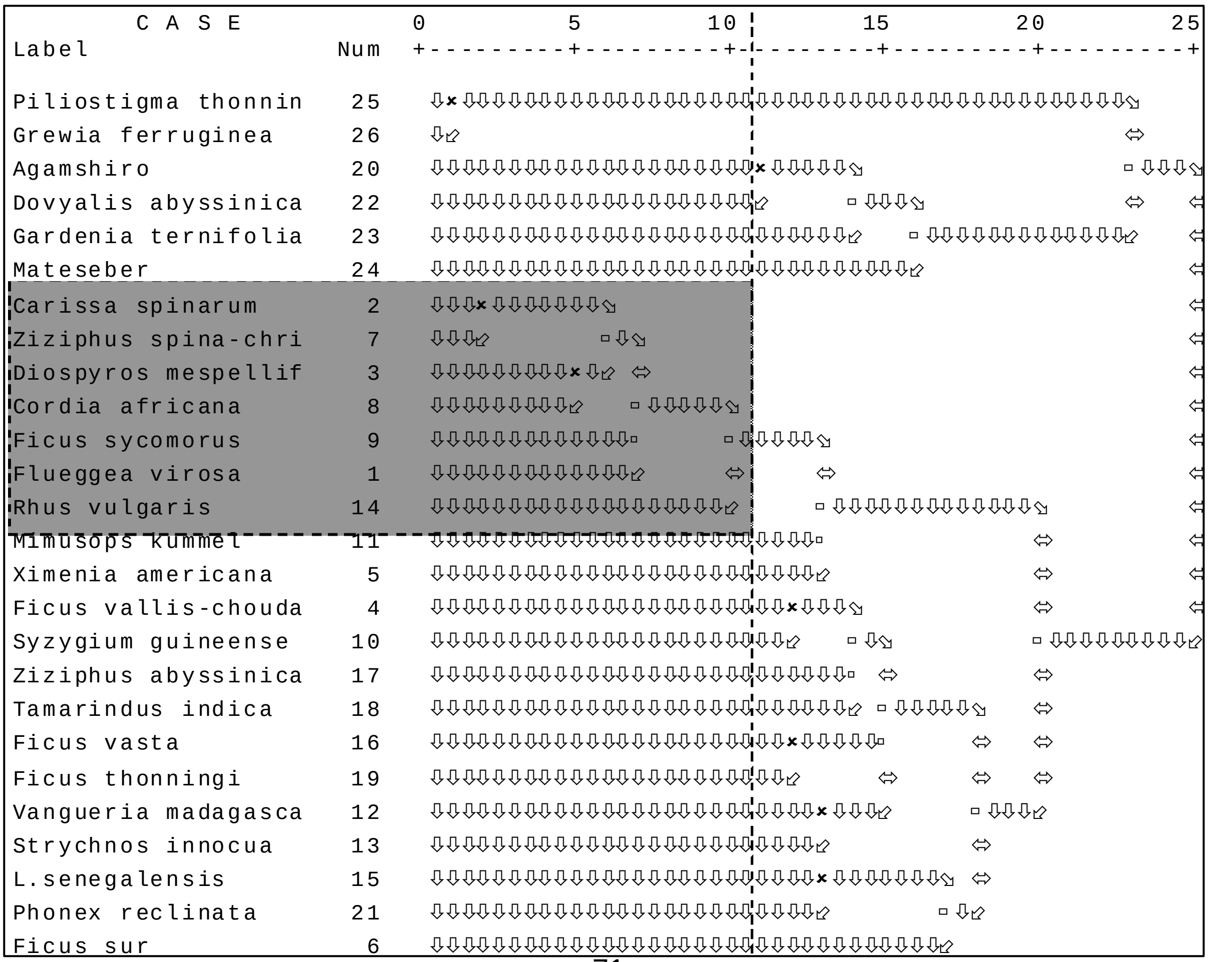


Table 4.10: Summary of free - list length, wild fruits cultural domain and consensus model of the study area

District / Site	No. of informants	No. of species mentioned	No. of species included in the domain	Mean free-list length per informant	Minimum - Maximum free-list	Mean estimated knowledge of informants (±SD)	No. of species included in the consensus model	Pseudo-reliabilty	List of species fitting the consensus key
Adiarkay (District)	47	31	26	10.09±4.17	4 to 22	0.63±0.22	7	1.0	*F.virosa, C.spinarum, D.mespiliformis, Z.spina-christi, C.africana, F.sycomorus, R.vulgaris*
Adiaregay (Site)	20	21	19	8.20±2.48	4 to 12	0.57±0.15	8	0.9	*F.virosa, C.spinarum, D.mespiliformis, Z.spina-christi, C.africana, F.sycomorus, R.vulgaris, M. kummel*
Bermariam (Site)	27	29	26	11.48±4.64	5 to 22	0.59± 0.24	9	0.9	*C.spinarum, X.americana, F.sycomorus, C.africana, Z.spina-christi, D.mespiliformis, M. kummel , R.vulgaris, F.virosa*
Debark (District)	45	31	23	8.02±3.33	3 to 20	0.63±0.24	7	1.0	*R.steudneri, R.abyssinica, C.spinarum, F.sycomorous, D.abyssinica, S.guineense, C.africana*
Debir (Site)	22	13	11	6.05±1.81	3 to 8	0.61±0.26	6	0.9	*R.steuneri, R.abyssinica, C.spinarum, F.sycomorous, C.africana, D.abyssinica*
Dibbahir (Site)	23	28	21	9.87±3.42	5 to 20	0.56±0.17	11	0.9	*X.americana, S.guineense, C.africana, R.steudneri, F.sycomorous, R.abyssinica, C.spinarum, F.virosa, P.reclinata, R.vulgaris, M. kummel*
Kurar (Site)	12	28	28	13.42±5.53	5 to 23	0.10± 0.43	8	0.6	*T.indica, X.americana, Z.mucronata, R.abyssinica, F.sycomorous, C.edulis, R.glutinosa, M.kummel*
Study area	104	52	46	9.64 ±4.39	3 to 23	0.73±0.19	4	1.0	*C.spinarum, Z.spina-christi, C.africana, F.sycomorus*

4.3.5 Typicality and consensus among informants

The estimated knowledge of informants (typicality), which is the percentage of agreement of their list to the model list, varied among informants within and between localities (Table 4.11). Informants with a score close to one are regarded to have a higher cultural competence and represent the community well, where in the event of complete consensus every one would score one. On the other hand, those informants who scored low value means that they do not follow the norm. Generally, informants at Debir recorded a higher mean estimated knowledge (0.61±0.26) while those at Kurar recorded very low (0.10± 0.43) indicating that the informants are very diverse in the latter and poorly represent the community they were drawn from.

Consensus analysis was carried out at study area, district and site levels. It was noted that the higher the scale of analysis the lower the numbers of species are included in the consensus model. Hence, at the study area level, informants consented only on four species (*C.spinarum, Z.christi, C.africana* and *F.sycomorus*). These are the expected typical answers for the interviewed culture of wild fruits species. At district level, both the Adiarkay and Debark consensus models appeared to compose seven species each. Where as, at site level the consensus key composed of eight species at Adiaregay and Kurar, nine at Bermariam, six at Debir and eleven at Dibbahir.

A higher pseudo-reliability value for the whole study area, districts and sites (except at Kurar) means that informants have a higher consensus on respective consensus keys. Moreover, the factor loadings in Eigen values table showed that the first factor is more than three times of the second. These two conditions are suggestive that informants are drawn from a single culture in their own respective localities. On the other hand, a relatively lower pseudo-reliability (0.61) at Kurar signifies that the consensus among the informants is low.

4.3.6 Species preference

It was noted that like in the case of cultural domain analysis species preferences of people are slightly undervalued, if not in the type, in the order of priorities when data was analyzed at higher (district) than at a lower scale (site). For instance, *R.abyssinica* followed by *S.guineense* were the most sought-after species at the aggregated data of Debark District (Figure 4.17). But at site level both species ranked first in their respective sites; *R.abyssinica* at Debir and *S.guineense* at Dibbahir. That means District level evaluations have somehow underrated species preferences of Dibbahir informants.

In total, as can clearly be seen in figure 4.17, *Z. spina-christi* (28.6%), followed by *Carisa* species and *D.mespiliformis* at par (23.8%) appeared to be species of higher preference in Adiarkay while at Debark *R.abyssinica* (37.5%) and *S.guineense* (29.2%) got a high fervor. At Kurar site of Dejen district, *T. indica* (80%) and *X. americana* (20%) were species of utmost preference.

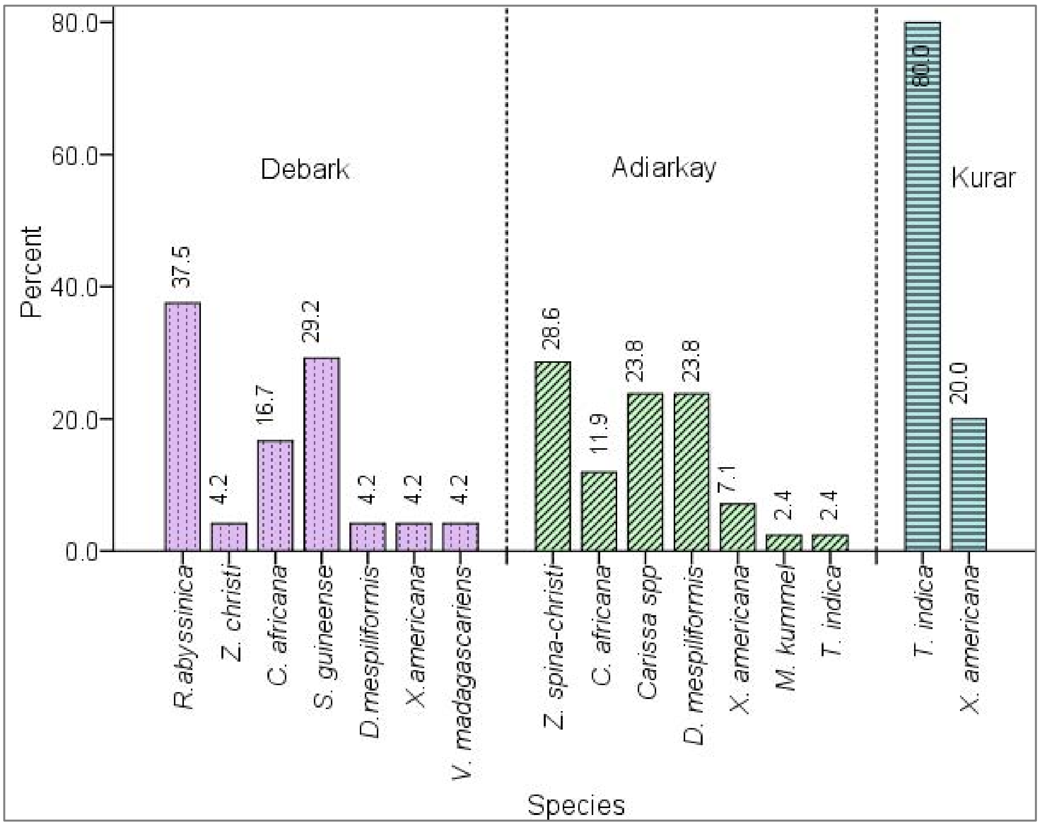


Figure 4.17: Species preferences of people at Debark, Adiarkay and Kurar

4.4 Wild fruit regeneration, population status and tree management practices

4.4.1 Natural regeneration and propagation

Natural self-regeneration is a commonplace in most wild fruit bearing species. However, regeneration of some hard seeded species like *Z.christi* is facilitated by animals like goats which during regurgitation process separate un-chewed or partially chewed fruits from the cud and discard them. As a result, seedlings are seen profusely regenerating from seeds collected in goats' Kraal and disposed off around the homesteads or where goats stray and crowd during heat of the day. Similarly, wild animals (mainly apes and monkeys) play an important role in the dispersal and regeneration of species like *D.mespiliformis*, *T. indica* and *X. americana*. Especially Colobus monkey is an important agent in seed dissemination particularly in churches and monasteries. Nevertheless, natural regeneration is very poor in species as *X. americana*.

It was also learnt that the majority of informants are not aware of other than seed methods of propagation for most of the wild fruit species. Even, for some species like *Ficus, Rubus* and *D. abyssinica* they do not account any means of regeneration and believe that they totally lack viable seeds. Perhaps, because of such a dearth of knowledge on regeneration mechanisms, the majority of informants (62.1%, N=66) acquire wild fruit species through retaining natural regenerants. Only 10.6% of the informants get hold of wild fruit species through direct planting or raising seedlings and transplanting. Cases in point are *C. africana* at Dibbahir, D*. mespiliformis* around Bermariam and *R. abyssinica* at Debir. Another 10.6% of the informants obtain wild edible fruit species (e.g. *R.abyssinica*) by transplanting of wildlings.

4.4.2 Plant population status

The populations of wild edible fruit trees seem generally decreasing precipitously. The majority of informants 72.5 %(N=91) voted for a declining trend while 15.4% are of the opinion that they are both at an increase and decrease depending on the species and habitat. Some, 7.7% of the informants do think that their status did not change while 4.4% claim an increasing trend. The primary reason cited for their decline was pressure from growing human population and subsequent severe forest degradation and conversion of forest land to agriculture. Besides, driven by the increased demand for firewood, construction and furniture in recent times cutting of remaining trees adds to their fast decline. In farmlands too, species as *Z.christi* do not fruit as they are cut or lopped very regularly. Another reason given for the perceived decline of wild fruit species is animal population pressure especially goat herd explosion particularly in Adiarkay area. Seedlings and coppices like in *Z.christi* are intensively eaten by cattle and goats that results in death and, if at all they could survive, they remain bushy and fail to grow into adult trees to bear fruits.

For some species as *M.kummel* and *X. americana* seedlings and coppices die due to fire damage while monkeys devour fruits along their seeds of the later to the extent of affecting its regeneration. These combined with its slow habit of growth, X*. americana* is in the verge of extinction especially in Adiarkay area. Now it is becoming restricted to church compounds and much degraded inaccessible areas. Similarly, *T. indica* and *M. kummel* populations are greatly reduced in Adiarkay district. Generally, in unprotected sites, among others, X*.*

americana, M. kummel, D. mespiliformis and *Carissa* spp. appear to be the most threatened species especially in Adiarkay area. On the other hand, the populations of some of these species sheltered in protected forests, churches and monasteries tend to be in *status quo* or are perhaps at an increase.

4.4.3 Tree management and cultural practices

The level of care and management of trees retained or planted in farms is generally very low. If they receive some degree of care and management, this is generally limited to practices such as lopping and pollarding. Out of 68 respondents who possess one or more edible fruit bearing species in their farms, 22.1% practice pollarding, 11.8% pruning, 5.9% lopping and 39.7% practice two or more of these operations. Lopping seems a common practice in species like *Z.christi, Ficus* species, *T.indica* and *C.africana.*

Nevertheless, pollarding or lopping practices are usually selective to the type of companion annual crop in the intercropping practices. For instance, *Z.christi* is pollarded or lopped if the companion crop is tef or sorghum but not niger seed in which case it is left intact. Cutting seems a norm in some species like *Carissa* for their thorniness as well as perceived soil fertility advantages. Regarding cultural management of trees, only few 20.6% (N = 68) respondents practice some form of cultural management like cultivation, weeding, supporting, fencing and in a few cases manuring of wildling transplants. Neither chemical fertilizers nor pesticides are used.

4.5 Wild fruit seasonal availability and utilization

4.5.1 Seasonal fruiting pattern

Fruits feature only in a specific season of the year and most local people do know exactly when the fruiting trees in their surroundings offer their bounty. Generally, season of fruiting and ripening appeared to vary by site, species and trees. As a result there are considerable overlaps in ripening among the different species both within and between localities. While some species ripe on specific seasons in a narrow range of time others stay long in fruiting or have wider time range (e.g. *R.abyssinica*). Still some others, as *Ficus* species*, C. spinarum* and *R. abyssinica*, ripe twice or thrice per annum in different seasons; usually the major fruiting season yielding a bumper harvest. As a result, fruits are available almost throughout the year the majority of them ripening from the month of January onwards (Figure 4.18). The September to January season generally records less number of fruits. Considering only the common species, 13 species appear to ripe from January to March and nine species between June and August.

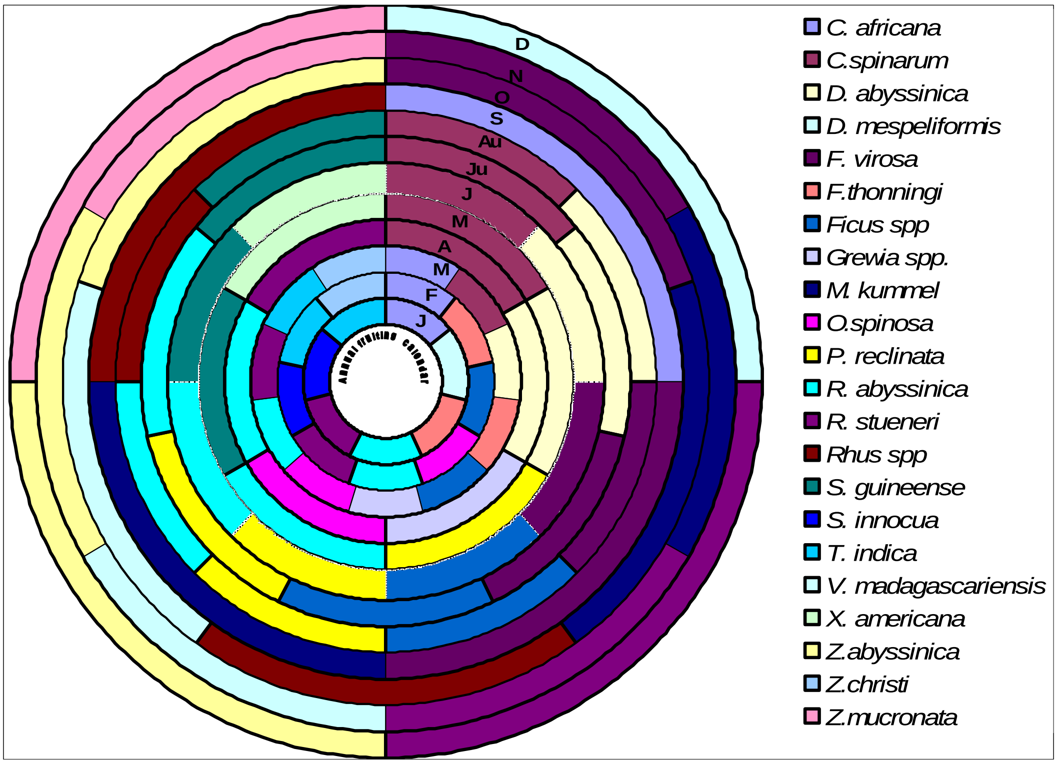


Figure 4.18: Fruiting calendar of wild fruits: concentric rings represent months outwards from January to December; number of colored segments within a ring signify the number of fruit species

4.5.2 Collection, consumption and frequency of use

The present findings disclosed that fruit gleaning and consumption are highly dependent on age. Fruits are mostly a domain of children though they are consumed by all walks of life to which the majority of informants gave their consents (70.7%, n=92). Of course, some twelve fruit species are dominantly or exclusively eaten by children that vary from site to site (Table 4.12). Adults in most cases regard wild fruits little food value and in the majority of cases avoid their consumption especially fruits like *Ficus* species with the excuse that, for instance, they harbor worms. Gender differences were not discerned to affect consumption of wild fruits. Interestingly, however, pregnant women were found to fond of eating wild fruits.

Moreover, fruits are harvested sporadically than on a regular basis (52.2% informants, n=92) though this is species dependent. Generally, fruits perceived higher importance and marketable like *Z. christi, S.guineense, M.kummel* and *Ficus* spp. are regularly collected and eaten, whereas fruits considered trivial like Rubus and Carissa species are consumed infrequently on an *ad hoc* basis or are limited to casual encounters. They are normally collected as a tangential business when regular activities are done; by children going about their activities like cattle herding and hunting, by women on fetching water, collecting wood and going for farm operations and by men as they walk past them.

Although there appeared no special category of fruits used only at times of famine, the intensity of use of some wild fruits was reported to ascend during times of hardship (Table 4.12). Especially people recount the widespread 1984/85 drought and the subsequent famine where several people especially the poor populace survived of increased consumption of wild fruits. Especially memories of reliance on *Z.christi*, which had intensively been consumed, bartered and sold during that time, are commonplace among several people.

4.5.3 Mode of utilization and nutritional significance

Most of the edible plants were found to be eaten fresh and raw as snacks or sometimes potion. Fruits of some species like *Z.christi,* Tamarind and *Ficus* species are eaten both at their fresh and dry states while *V. madagascariensis* fruits are consumed dried. In some seven species of fruits, so to say, some form of home processing as boiling, roasting and fermentation are practiced (Table 4.12).

Fruits are processed into refreshing juice either by boiling or adding lukewarm or cold water to which sometimes sugar or honey is added. *Carissa* juice is drunk especially at Islamic holidays like Maulid. Fruits are fermented with the addition of *Rhamnus prinoides* leaves to brew local beers "*Tela*" and "*Tej*" (Mead) or without it to prepare "Beerz" (a Hydromel) or are simply added to flavor other drinks. A night long infusion of a macerated and fermented tamarind pulp known as "*Areke*" (a local drink) is eaten by dipping bread. *P. reclinata* fruits are eaten by damping for a week to facilitate ripening.

It was also found out that people in the study areas do not explicitly recognize nutritional contribution of wild fruits, rather they value them a snack to filling up a ravenous stomach. However, when they are asked their reasons for preferring one species over the other they implicitly refer to their nutritional significance as their answers usually emerge as "because it becomes body." However, empirical analysis of the nutrient composition of some of the marketable species brought to light that they are in fact loaded with important nutrients. Accordingly, as shown in Table 4.13, *M. kummel* is excellent in Vitamin C while it also contain a good level of carbohydrate, fat and proteins. *D. mespiliformis* is rich in minerals (phosphorus and iron) and fat. Similarly, tamarind is good at having proteins while *Z.spina-christi* is very rich in phosphorus and contain a good amount of carbohydrate, vitamin C, protein and ash.

Table 4.11: Wild fruits of various categories

Attributes	Number (%), N=48	Fruit species
Fruits of dominantly children category	12 (25%)	*F. virosa, Ficus spp., F.thonningi, Rhus spp., S. oncoba, S.africana, S.innocua, Rubus spp., E. ventricosum, C.africana, Grewia spp, P. reclinata*.
Fruits their consumption intensified during famine	7 (14.6%)	*R. abyssinica, M. africana, Ficus spp, F.virosa, Carissa spp., Rhus spp., P. reclinata*
Fruits subjected into some level of processing	7 (14.6%)	Juice making- *Carissa spp, Tamarind, C.africana, Z.christi* Local beer making- *Z. Christi, R.abyssinica, Rubus spp., Tamarind, Ficus spp., C. africana* Flavor drinks- *Cordia africana, Carissa* spp.
Fruits with unpleasant characteristics	15 (31.3%)	*C. africana* - unripe fruits cause transitory stomach cramp, queasiness, affects lung *C. spinarum* - excessive use cause a feeling of queasiness, burning sensation of stomach, diahorea, *D. abyssinica* - difficult to eati other foods afterwards, tartness *D. mespiliformis* - sharp taste. *F. virosa* - unripe fruits transitory stomach cramp *Ficus* spp. - unripe, ant or worm attacked fruits transitory stomach cramp, nauseate goats too *L. senegalensis* - seeds cause an instantaneous death of goats and camels *M. kummel* - gastric problem, mouth drying, a feeling of thirsty *O. ficus-indica* - causes constipation *R. abyssinica* - burning sensation of the stomach, throat ache and skin irritation, juice cause a feeling of *Rhus* species - difficult to eat other foods afterwards *Rubus* spp - burning sensation of the stomach *S. guineense* - burning sensation of the stomach, vomiting, mouth colouring, juice cause lung sickness *T. indica* - tartness or astringency *Z.christi* - ant or worm attacked fresh fruits cause a transitory stomach cramp, excessive use cause queasiness

4.5.4 Undesirable effects with the consumption of wild fruits

The majority of respondents across the study areas (73.9%, n=92) complained about and unanimously asserted some 15 wild fruits species to incite harmful reactions to dissuade people and influence on their popular appreciation (Table 4.12). These are generally some transitory health problems expressed as nausea, vomiting, uncontrolled defecation, constipation, heartburn, tartness, etc. Sicknesses effects are reportedly pronounced especially when fruits are eaten unripe usually on a fasted stomach or are worm infested or taken in excess amount.

Besides, following a consumption of some species it presents difficulty to eating other foods like pepper as they leave a transitory feeling of tooth-ache. Some fruits are considered disagreeable simply because they are sour or tart to the mouth. Nevertheless, people have got mechanisms to remove some of these effects. For instance, *M. kummel* fruits and tamarind seeds are sometimes eaten roasted to avoid the astringency. The tartness in fresh fruits or infusions of tamarind is overcome by adding a neutralizing agent (lime) known locally as "*Abole*". Surprisingly, some wild fruits were also reported to affect not only humans but also animals. For instance, Ficus spp. were reported to also nauseate goats while seeds of L.senegalensis fruits instantaneously kill goats and camels. Sadly, the exocarp of the later specie is edible by humans.

Table 4.12: Nutrient content of some major wild edible fruits (per 100g edible portion)

Fruit species	Percent						mgs/100g		
	Moisture	Fat	Protein (Nx6.25	Crude Fiber	Ash	Carbohydrate (including	Phosphorus	vitamin C	Iron
Mimusops kummel	13.1	1.62	2.19	20.46	2.60	80.49	31.28	148.6	2.95
Diospyros mespiliformis	32.6	1.65	1.44	27.74	2.75	61.56	46.81	13.41	19.33
Tamarindus indica	41.29	1.08	2.38	7.72	2.28	52.97	37.78	11.31	2.08
Ziziphus spina-christi	7.64	1.18	3.21	4.73	7.23	80.74	261.78	35.15	-

4.6 Non-fruit functions and services

In the study areas, every conceivably wild fruit bearing species is valuable in several other ways pertaining to social, economic and ecological services and even except in a few species, food value has rather a subordinate role. For 13 wild fruit species across the study areas, more than 21 non-food use categories were recorded (Figure 4.19). Comparison of species of more than one uses showed that fuel wood (19.4%), construction (13%) and fencing (13%) are dominant use categories.

On a species basis, *Z.christi* has the greatest number of uses (11, 15.07%) followed by *C.africana* and *T. indica* (10, 13.7%) at par. The various uses of wild fruit bearing species is briefly summarized in table 4.15 and highlighted as follows.

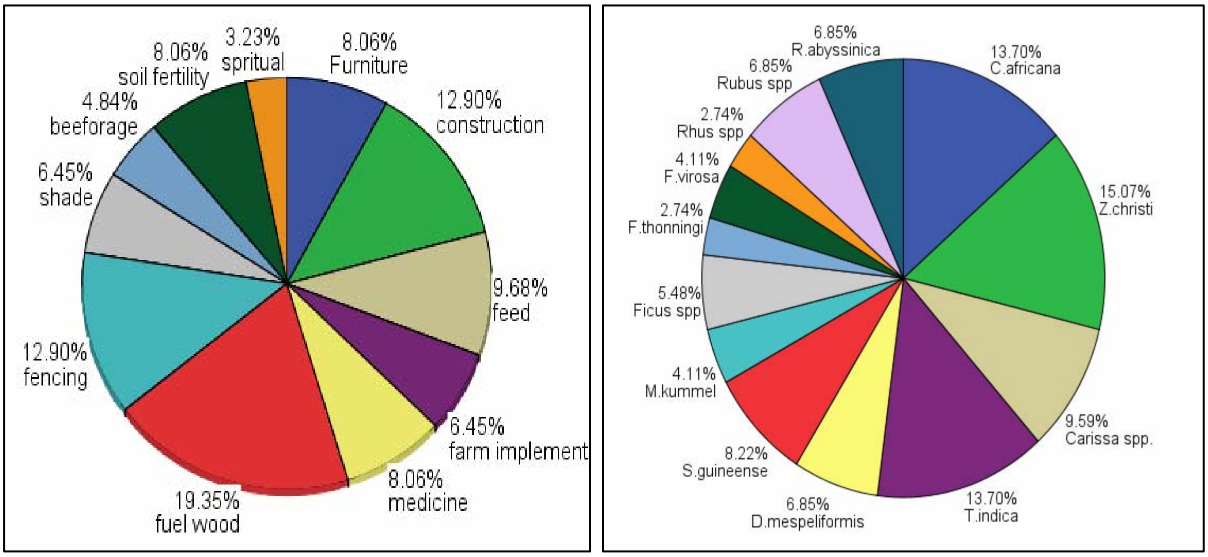


Figure 4.19: Percent non-fruit use (left) and contribution of wild fruit species to the total use categories (right)

4.6.1 Socio-economic and cultural values

When they are eaten for their food or nutrition role, some species as *R. abyssinica* are widely recognized to circuitously improve health conditions. Other species are directly used in folk medicine and improve health conditions. For instance, species as *M. africana* are reputable and appear in the top list of prescriptions of local medicines. Looking at some major species, tamarind is frequently reported to have a purgatory role and high medicinal value against malaria and any form of stomach trouble like a cure against amoeba and is good against vomiting. Leaf decoctions of *Z.christi* cure itch problems on infants while its ground leaves mixed with butter are used as hair ointment against Dandruff. *R.abyssinica* was most frequently mentioned as a good tapeworm and round worm expectorant.

Wild fruit tree species are also widely used for house construction, furniture, farm implement, hand tools, etc. *C.africana* is most precious in furnishings and carvings. Most houses in the study areas being *tekuls* (huts) some wild edible fruit bearing plant species are highly valued for house or church constructions. Besides, some species are frequently used for either live or dead fence. Several others serve a feed for one or more categories of livestock. Moreover, almost all fruiting species support and sustain the life of wild animals and birds.

Table 4.13: Comparison of soil properties beneath the root zone and out of crown projection area of *T. indica* and *Z.spina-christi* trees (* Significant at t<0.05)

Parameters	Mean		Paired differences		t	df	Significance (2-tailed)
	Within crown Projection area	Outside crown Projection area	Mean	Standard Error			
Tamarindus indica							
Total N (%)	0.39	0.22	0.17	0.05	3.48	4	0.03*
Available P(ppm)	20.31	39.63	-19.31	19.55	-0.99	4	0.38
Organic Carbon (%)	3.58	2.20	1.38	0.44	3.10	4	0.04*
pH	6.15	6.14	0.01	0.14	0.06	4	0.96
CEC($Cmol_cKg^{-1}$)	28.07	36.20	-8.13	11.07	-0.73	4	0.50
Ziziphus spina-christi							
Total N (%)	0.26	0.22	0.04	0.06	0.80	4	0.47
Available P (ppm)	46.16	30.12	16.04	13.27	1.21	4	0.29
Organic Carbon (%)	2.26	2.27	-0.01	0.48	-0.02	4	0.98
pH	6.09	6.06	0.03	0.08	0.40	4	0.71
CEC($Cmol_cKg^{-1}$)	40.20	31.60	8.60	4.63	1.86	4	0.14

4.6.2 Environmental/Ecological services

Some fruit bearing wild plants as *C.africana* and *Carissa* spp. are locally believed to have a soil fertilizing effect. These claims were validated empirically by a laboratory analysis of nutrient contents of soils beneath the trees of some important wild fruit species that frequently appear in farms. Accordingly, it was found out that tamarind trees have a significantly higher total nitrogen (0.39) and organic carbon (3.58) in the root rhizosphere than outside crown projection area with a corresponding figure of the latter 0.22 and 2.20, respectively (Table 4.14). Similarly, though statistically non-significant, there appeared a higher level of available phosphorus and CEC near the tree than outside crown projection area in *Z.spina-christi*. These results suggest that brought into agroforestry these species could be well compatible with annual crops. Besides, several species serve shade for both humans and animals while some are recognized as a good source of pollen for bees.

4.6.3 Spiritual or cultural values

Some species as are intensively used in rituals. For instance, *Z. spina-christi* is widely used a sign of condolence expression especially in Islamic religion. *F.virosa* is used in crop yield predictions. Wild fruits are also integral components of songs, adages, blessing, etc.

Table 4.14: Non-fruit utilities of wild fruit bearing plant species

Function	Type of species used
Socio-economic and cultural values	
Nutraceutical	*R. abyssinica, Z.christi, S. guineense, Carissa* spp., *M. africana* and *T. indica*
Firewood	Except perhaps a few species as Rubus, potentially all fruit trees are used
Furnishings and carvings	*C.africana, Z.christi, D.mespelliformis, S. Guineense, Ficus spp*
Farm implement	*M. Kummel* and *Z.christi* are highly valued
Building material (house, church)	*C.africana, Z.christi, Carissa, Tamarind, D.mespilliformis, S.guineense, M.kummel, Rubus* spp..
Live or dead fence	*Z.christi, Carissa, Rubus spp., R. Abyssinica, D.abyssinica*
Livestock feed	*C. africana, Z.christi, F.thonningi, D.abyssinica*
Food for wild animals and birds	Almost all fruiting species
Divert wild animals away from crops	*F.virosa* and *T. indica*
Other day-to-day activities and services	Fumigation*(R. abyssinica),* tool handle *(Rhus),* toothbrush *(D. abyssinica* and *P. reclinata),* musical instrument *(O.spinosa),* Kraal making*(Tamarind),* sticks (*Grewia sp., F.virosa),* carpet, hut, bag, floor brush, wrapping up of corpus of deceased on entombment *(P. reclinata),* hide coloring *(X.americana)* , *etc.*
Environmental/Ecological services	
Soil fertilizing effect	*C. africana, Carissa* spp. and *R.abyssinica*
Shade, social functions	*C.africana, Z.christi, Tamarind, D. mespeliformis* and *Ficus spp.*
A good source of pollen	*R. abyssinica, C.africana* and *Carissa* species
Spiritual or cultural values	
For washing the body of a deceased	*Z. spina-christi*
Condolence expression	*Z. spina-christi*
Yield prediction	*F. virosa* and *C. spinarum*
A component of songs	*X.americana*

4.7 Income generation from wild fruits

4.7.1 Marketable species and seasonal availability

Overall, depending on the locality some ten species of wild fruits are sold; viz., *Carissa* spp., *C. africana, D. mespiliformis*, *Ficus* spp., *M. kummel*, *R. abyssinica*, *S.guineense*, *T. indica*, *X. americana* and *Z. spina-christi*. On a district basis, some five species at Debark and seven at Adiarkay were reported marketable. At Kurar area of the Dejen market, *T.indica* and *X.americana* appear dominant. In addition, *C. africana*, *Ficus* spp. and *M.kummel* were reported marketable. Nonetheless, despite informants' reports of their marketability, *C.africana* and *X.americana* at Adiarkay and *S. guineense* at Debark failed to be captured in a year round market inventory (Table 4.16) suggesting that market appearance of fruits varies from year to year. Moreover, while some of the fruits such as *M. kummel* were encountered across all location markets others are sold only in specific market places, for instance, *D. mespiliformis* only in Adiarkay.

Table 4.15: Types of wild fruits sold at Adiarkay and Debark markets by month

Species/month	January	February	March	April	May	June	July	August	September	October	November	December
					Adiarkay							
Carissa species									xxxx			
Diospyros mespiliformis	xxx-											-xxx
Mimusops kummel	xx--									-xx	xxxx	xxxx
Tamarindus indica		-xxx	xxxx	xxxx	x---							
Ziziphus spina-christi	---x	xxxx	xxxx	xxxx	x---							
					Debark							
Cordia africana			xxxx	xxxx	xxxx							
Mimusops kummel									xxxx	xxxx		
Rosa abyssinica				xxxx	xxxx							
Ziziphus spina-christi		xxxx	xxxx	xxxx	xxxx	xxxx	xx--					

It was also noted that the duration of stay on sale varies from species to species. While *Z. christi* and tamarind are available for most part of the year, most others appear only for a short period of time. *Z.christi* and tamarind were recorded respectively on 14 (70%) and 13 (65%) of the 20 marketing days at Adiarkay market. There appeared also windows where wild fruits are completely absent in the market which is the November to January period at Debark and June to August at Adiarkay. But as shown in figure 4.18, there are some species ripening by these times in the wilderness. This shows that despite their availability some fruits are not marketable so that town dwellers do not have access to.

4.7.2 Markets, trading routes and transportation

Most wild fruits are sold at the near by rural markets. Adiarkay, Debark and Dejen are the immediate markets of disposal in the study areas. At times, in areas like Debark schools are also resorted to sell wild fruits to serve as snacks for school children. But in a few instances and few fruits they are transported to distant markets. Traders transport them to bigger markets like Gondar, Tigray region markets and Addis Ababa. *Z.spina-christi* is sometimes shipped to neighboring countries like The Sudan and Eritrea (pre Ethio-Eritrea war). Similarly, tamarind is said to be exported to some Arab countries like The Sudan.

As regards transportation for market disposal, most people carry by loading on head or back while some are served by animal back transport (donkeys and horses) and occasionally buses. For instance, at Debark, 77.2%, 19.3% and 3.5% of informants transport fruits by human back, animal back and vehicle in that order (Table 4.17). However, both means of transport are bound to lead to high fruit wastage because of physical damage and improper ventilation. Some fruits like *S. guineense* are totally unfit for animal back loading as they can easily be damaged. As a result, human back remains the major means of transporting of such species, which is still not free of physical damages while it also hampers large quantity fruit disposal. Fruits are usually bagged for transportation with local containers like *"kimba"* (a small basket) or basket or bags. For instance, 54.4% of sample fruit sellers at Debark carry their fruits in bags (polyethylene, cloth, burlap sacks, etc.) while the rest (45.6%) use baskets the latter of which could be regarded relatively safe as it can reduce compression and squashing damages for its rigidity.

4.7.3 Fruit transaction and handling

Out of 24 marketing days visited at Debark, 15 marketing days recorded wild fruits that are sold by a total of 74 people (on average five vendors per day) while nine markets (37.5%) recorded no fruit vendors. Of the total 57 sample vendors contacted, 14 (24.5%) appeared only once, twelve (21.05%) twice, five (15.6%) thrice and in one case four times. At Adiarkay, 81 vendors were recorded over 20 marketing days of which 77 of them were contacted (on average four vendors per marketing day). In this case, some 47.4% of the vendors appeared once while two vendors were encountered up to seven times.

Table 4.16: Characteristics of wild fruit transaction at Debark market

Number / Percent	Type of stall		Type of vendor		Frequency of sale			Mode of transportation			Container used		Customer of fruit collectors				Customer category		
	Permanent	Temporary	Retailer	Collector	Daily	Weekly	Occasionally	Human back	Animal Back	Vehicle	Basket	bag	Retailer	Consumer	Both	Wholesaler	Men	Women	Children
N	27	30	28	29	26	1	29	44	11	2	26	31	29	23	6	3	1	28	25
%	47.4	52.6	49.1	50.9	46.4	1.8	51.8	77.2	19.3	3.5	45.6	54.4	47.5	37.7	9.8	4.9	1.9	51.9	46.3

Fruit transaction is done either in the open air exposed to full sunlight (usually by wholesalers / collectors) and in market stalls by traders. As shown in table 4.17, at Debark the majority of wild fruit vendors are people with temporary stalls (52.6%) than permanent (47.4%) and most are people who collected the fruits (50.9%) than retailers (49.1 %). Similarly, at Adiarkay 88.9 % (n=24) of vendors are those with temporary stalls and 86.9 %(n=20) are fruit collectors than retailers. It is also interesting to note that some fruits as tamarind and *Z.spina-christi* are purchased at the doorstep of traders' houses and or shops. Sometimes fruits like tamarind are sold on a contractual basis where, for instance, people from Dejen town as well as metropolis contract local collectors.

Surprisingly, retailers are almost totally women (96.6%) that mostly dwell in towns while the reverse is true with collectors who sale whole, in which case 92.9% were men. Regarding frequency of marketing, the majority of vendors (51.8%) at Debark are those who randomly enter the markets and sell occasionally as needed while 46.4 % sell on a daily basis. Fruits are purchased by consumers and retailers than wholesalers about which some 75% of the respondents agree. When this is seen in terms of gender and age at Debark, women are the major customers (51.9%) followed by children (46.3%) while men are involved very rarely (1.9%, N=54). At Adiarkay, however, all age groups tend to be customers of fruits. The average quantity of wild fruits of all species brought to market per trader per day is generally low, e.g. only 12.8 kg at Debark market. Again, out of this amount a significant portion remains unsold in the same day about which some 43% of the fruit vendors consented.

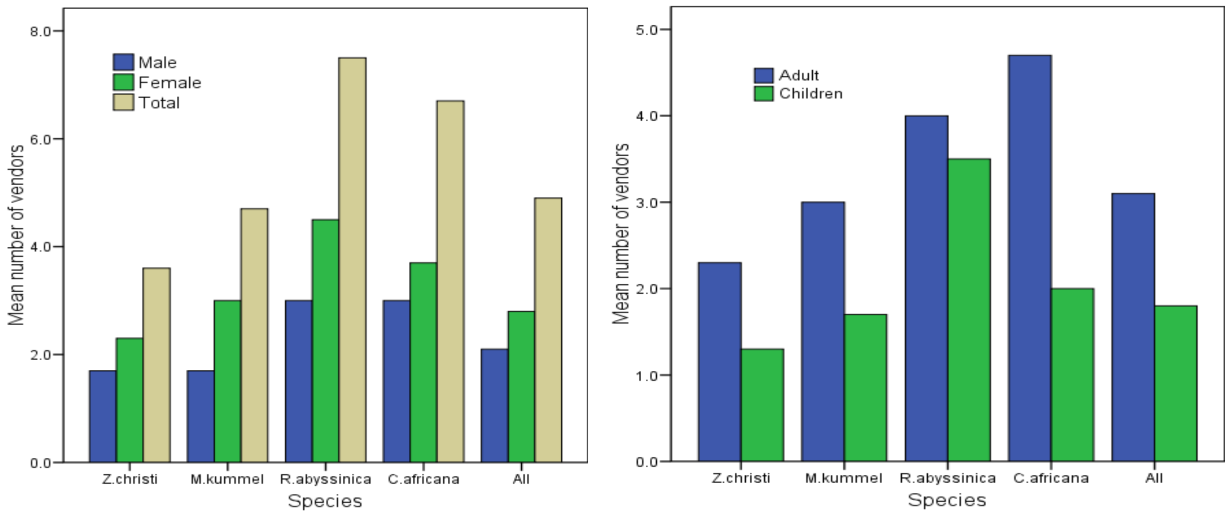


Figure 4.20: Wild fruit species market disposal day^{-1} by gender (Left) and age (right) at Debark

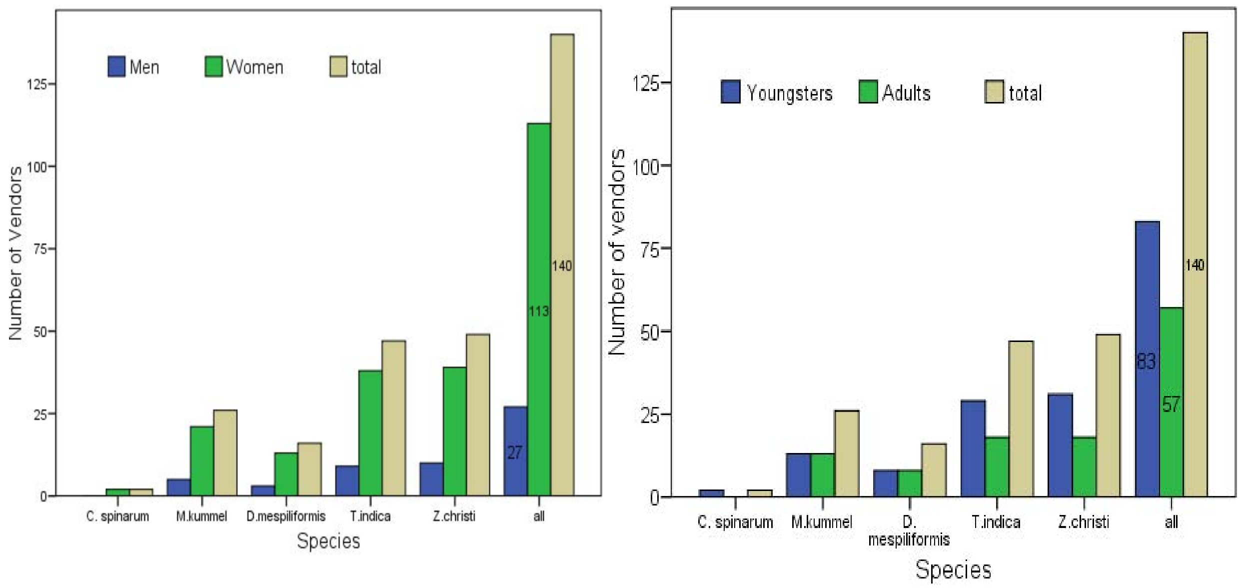


Figure 4.21: Wild fruit species market disposal by gender and age at Adiarkay (N=81)

Some 58.7% of respondents in the study area reported that children are the main actors in wild fruit transactions. Nevertheless, against such assumptions of informants at Debark most wild fruit vendors appeared to be adults (63.5%) than children (36.5%) while within adult category women (56.8%) are more involved than men (43.2%), Figure 4.20. But at Adiarkay, 59.3% of the vendors were youngsters while again gender-wise 80.7% were women (Figure 4.21). Religion-wise, mostly Islam traders are involved in wild fruits retailing as is the case with most other commodities. Although collection and marketing of fruits in most cases is considered the domain of rural people, at times the urban dwellers themselves do also get involved. For instance, during peak ripening season of *R. abyssinica* urban people from Debark town use to swarm the surrounding forests and glean fruits.

Market preference of fruits appeared to vary by site. While *R. abyssinica* (50%) and *Z.christi* (42.5%) are most preferred species at Debark market, *Z.christi* and *D. mespiliformis* appeared to have high fervor at Adiarkay. Because of this, several vendors deal with these species and dispose them at relatively larger quantities. For instance, Z*. spina-christi* recorded the largest volume per marketing day both at Debark (16.6 kg) and Adiarkay (4.3 kg) markets. Buyers' preferences are generally centered on color, taste, shelf life and pest or disease freeness. Of course, this varies with the type of species where while color is very important in *Z.christi* and *M.kummel*, taste is sought in *R. abyssinica* and *C. africana* and both shape and taste in tamarind.

Generally, wild fruits fetch a very cheap price especially at peak fruiting season that also varies from location to location (Table 4.18). The highest price, 60 Ethiopian Birr (ETB[*]) per quintal, was that reported for tamarind fruits. Fruits are usually sold with local measurement units like Cans (known as "*Asketila*"), *"kimba"* or baskets, bags, on a number basis or simply by judgment. Fruits of *D. mespiliformis* and *X.americana* are often sold on a number basis while tamarind fruits are usually sold on judgment.

Table 4.17: Prices of wild fruits in the study areas (2006 - 07)

Species	Distance transported (km)	Price kg^{-1} (Birr)
Ziziphus spina- christi	15-35	0.40-3.00
Mimusops kummel	20-36	1.10-1.50
Rosa abyssinica	16-29	2.50-3.00
Carissa sp.	5-15	1.00-1.35
Cordia africana	28-37	1.30-1.75
Diospyros mespiliformis	10-20	1.00-1.75
Tamarinus indica	15-25	2.00-6.00

Altogether, *T.indica* and *Z.spina-christi* are fruits with relatively better prices. This, however, varies with season and how they are sold (retailed, whole sold or contracted) where retail price is comparatively higher. It was also found out that in some instances fruits are exchanged for other goods, a good example being *Z.christi* that is exchanged for salt at

[*] One Ethiopian Birr = 0.10405 USD (July 2008 exchange rate)

Adiarkay area. The profit out of sale of wild fruits is also very marginal, which is less than 10 ETB per quintal.

As a result, the income from sell of wild fruits is seen very insignificant (78.1% informants), which it is used only to supplement the poor people daily subsistence like salt, coffee and in some cases for clothing and schooling of children. Nevertheless, despite the meager income, some very needy people are able to create assets out of such business.

Most fruits like *S. guineense* and *D. mespiliformis* are generally sold fresh right after harvest for their perishability and perhaps urgent economic needs. As a result, they incur high post-harvest losses in the marketing process. On the other hand, for their relatively longer shelf life fruits like *M. kummel,* some *Ficus* species and *R. abyssinica* are sold and consumed in the fresh-dry state continuum or nearly dried. A few others like *Z.christi, T.indica* and some *Ficus* species are eaten or sold both at their fresh state and mostly after they are dried and stored. Especially *Ziziphus* species are highly durable and can be stored up to even a year. Generally, market fruit handling appears sub-optimal and fruits are inferior in quality. All sorts of fruits (different sizes; raw, ripe and over ripe; damaged, bruised, etc.) appear together and there are no any value addition techniques practiced at the moment.

4.8 Description of the homegardens

4.8.1 Garden age, type, distance, orientation and shape

The age of gardens would provide a hint on the history and trend of fruit production. As shown in table 4.19, gardens were established from as low as one to twenty-one years (x,¯ =8.6 years), the majority (45.7%) falling between 6 to 10 years of age (Figure 4.22). Wogelsa and Zeghe gardens appear to be relatively the youngest (x,¯ =3.8) and oldest (x,¯ =12.3), respectively (Figure 4. 21).

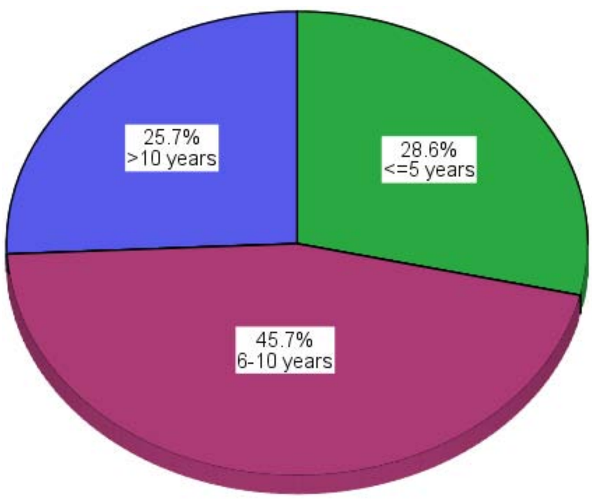


Figure 4.22: Frequency of gardens by years of establishment (N=70)

Their number varying between one and two, the homegarden plots generally occur in three forms: clearly differentiated from the rest of the farm and adjoined to a house, adjoined to a house but undifferentiated with the main field and completely disjoined from a house and located far away. Although it varies by site, as table 4.19 demonstrates the dominant types of gardens tend to be those single in number and adjoined to a house (33.6%, N=147). However, the majority of gardens at Andassa (62.1%) and Arbayitu (46.7%) are located far-off from residences, on average 539.9 and 219.8 meters away, respectively. The closest gardens were recorded at Woinma and Zeghe (x,¯ = 3.2 meters). At Wogelsa two gardens that are adjoined to a house and outlying farm (57.9%) are very common.

With respect to the relative orientation of garden to a house, the most common types of gardens are those at the backyards (28.3%) which are true for most gardens at Robit (66.7%), Zeghe (45%), Wangedam (36%) and Arbayitu (100%). Besides, the dominant shape of garden plots appears to be rectangular (59.2%), which is mainly manifested at Robit (73.7%), Woinma (80%) and Arbayitu (93.3%) sites.

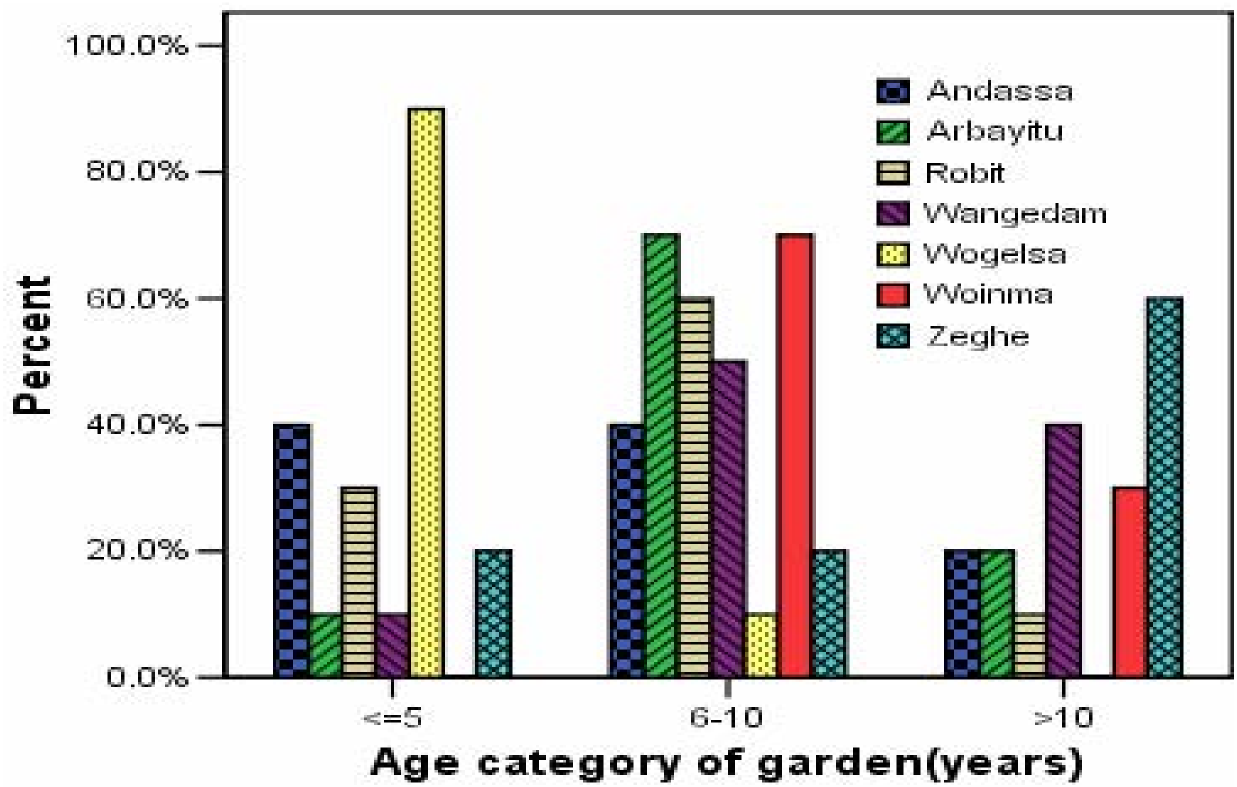


Figure 4.23: Frequency of gardens by year of establishment for individual sites

4.8.2 Garden size

By and large garden plots are subsets of the homestead land from which most households allocate from less than a quarter to half for fruit production. The rest of the homestead (hereafter taken to mean garden) is used for other annual and perennial crops and trees. The average homestead landholding per sample households appears to be 0.44 ha and there is a statistically highly significant difference among sites (Table 4.20). Wangedam has a significantly lower (P<0.01) homestead plot per household (0.25 ha) compared to Andassa (0.55ha) and Zeghe (0.58ha).

For the sake of better comparison of otherwise highly variable sizes, the gardens included in the study were suitably divided into three categories based on the median value increment: small (<,_ 0.25 ha), medium (between 0.26 and 0.50 ha) and large (>0.5ha) where the majority (46.9%, N=69) fall under small size category (Table 4.20). These garden size categories varied significantly (P<0.01) from each other in terms of average garden size per household (Table 4.21).

The average total landholding per household of all gardens was 1.4 ha. The smallest and largest landholdings were recorded respectively at Zeghe (0.59ha) and Woinma (1.93ha) sites. Zeghe recorded a significantly lower total land to all but Wangedam and Arbayitu (P<0.01), Table 4.21). The farms included in the study were also divided into three groups based on total farm size: Small (<,_ 0.5 ha), medium (0.51-1.0 ha) and large (>1.0ha) where the majority of farms (87, 59.2%) fall under large farm size category (Table 20). The three farm size categories differed significantly (P<0.01) from each other (Table 4.21).

Table 4.21 further compares households with respect to the proportion of land allocated to homegardening that varies among households, sites and garden size categories. Households' garden land allocation varies between 2.6 and 100% with a mean value of 43.7%. Similarly, sites differed significantly in their average garden land allocations where the highest and least values were recorded at Zeghe (97.5%) and Wogelsa (27.5%).

It was also noted that households with small farm sizes allocate a significantly larger land for gardening (86.2%) compared to medium (54.7%) and large (26.4%) farm size categories (P<0.01). Accordingly, although total landholding has a significant positive correlation with garden landholding (R =0.52, P<0.01) its correlation with garden land allocation turn out to be negative (R= - 0.57, P<0.01). This indicates that although households with small total land allocate proportionately more land to gardening they still hold smaller homestead plots.

Table 4.18: Garden characteristics of the study areas

Site	Garden age			Garden type					Garden shape						Garden location								Distance from a house		
	in years			Adjoined to a house only	Two (close to house & outlying fields)	In continuum with the farm	Far off residence	Two (close to house & far off)	Circular	Rectangular	Square	Irregular	Triangular	Rectangular + irregular	Back only	Encircling the house	In the front only	Far off	Back + front	Encircling + far off	Front + far off	Back + far off	in meters		
	Min.	Max.	Mean	1	2	3	4	5	1	2	3	4	5	6	1	2	3	4	5	6	7	8	Min.	Max.	mean
All	1	21	8.61±4.55	33.6	30.8	6.8	20	8.9	2.7	59	12	20	4.8	1.4	28	24.4	19	23	0.8	3.1	0.8	0.8	1	2000	154.61±359.99
Andassa	4	13	7.2±3.01	13.8	10.3	13.8	62	0	0	38	0	48	14	0	6.9	6.9	14	69	3.4	0	0	0	5	2000	539.90±548.36
Robit	3	15	7.0±3.53	47.4	36.8	15.8	0	0	0	74	21	5.3	0	0	67	0	0	33	0	0	0	0	2	1000	98.26±248.54
Wogelsa	1	10	3.8±2.53	42.1	57.9	0	0	0	0	32	68	0	0	0	16	31.6	42	5.3	0	5.3	0	0	2	250	74.44±92.28
Zeghe	4	20	12.3±6.24	5	50	0	5	40	15	35	0	25	15	10	45	40	10	5	0	0	0	0	1	6	3.15±1.57
Wangedam	5	15	9.4±3.41	56	28	4	12	0	76	4	20	0	0	0	36	12	28	8	0	8	4	4	2	100	10.24±19.25
Woinma	6	15	10.4±2.89	52.6	36.8	10.5	0	0	0	80	0	20	0	0	10	60	15	10	0	5	0	0	1	10	3.19±2.87
Arbayitu	4	21	10.2±4.34	20	0	0	47	33.3	6.7	93	0	0	0	0	100	0	0	0	0	0	0	0	2	1500	219.77±469.26

Table 4.19: Comparison of sites by the frequency of garden and total land size categories

Type	Category	Site							Total number of gardens	%
		Andassa	Robit	Wogelsa	Zeghe	Wangedam	Arbayitu	Woinma		
Garden land	Small (0.25 ha)	31.0	47.4	78.9	35.0	68.0	53.3	20.0	69	46.9
	Medium (0.26 - 0.50 ha)	55.2	21.1	21.1	20.0	32.0	33.3	60.0	53	36.1
	Large (>0.5ha)	13.8	31.6	0.0	45.0	0.0	13.3	20.0	25	17.0
Total land	Small (0.5 ha)	13.8	5.3	15.8	55.0	24.0	6.7	5.0	27	18.4
	Medium (0.51-1.0 ha)	31.0	15.8	5.3	30.0	24.0	26.7	20.0	33	22.4
	Large (>1.0ha)	55.2	78.9	78.9	15.0	52.0	66.7	75.0	87	59.2

*Figures with different letters are significantly different from each other (Bonferroni, P< 0.01, one-way ANOVA)

Table 4.20: Comparison of sites and garden size categories for mean differences in garden size, total land size, and garden land allocation (± SE)

Site	Mean garden size (ha)	Mean total land size (ha)	Garden land to total land ratio (%)
Andassa	0.55 ± 0.09^{A}	1.44 ± 0.24^{A}	45.42 ± 4.52^{A}
Robit	0.48 ± 0.08^{AC}	1.77 ± 0.19^{A}	28.27 ± 4.36^{A}
Wogelsa	0.29 ± 0.02^{AC}	1.62 ± 0.18^{A}	27.45 ± 6.21^{A}
Zeghe	0.58 ± 0.09^{AB}	0.59 ± 0.09^{B}	97.50 ± 2.50^{B}
Wangedam	0.25 ± 0.03^{C}	1.11 ± 0.14^{AB}	37.20 ± 6.19^{A}
Woinma	0.48 ± 0.05^{AC}	1.93 ± 0.24^{A}	32.81 ± 4.75^{A}
Arbayitu	0.39 ± 0.06^{AC}	1.42 ± 0.17^{AB}	34.58 ± 6.63^{A}
Size category			
Small	0.21 ± 0.009^{A}	0.29 ± 0.336^{A}	86.24 ± 4.62^{A}
Medium	0.47 ± 0.008^{B}	0.84 ± 0.275^{B}	54.74 ± 4.77^{B}
Large	0.99 ± 0.099^{C}	1.95 ± 0.079^{C}	26.39 ± 2.12^{C}

4.9 Agroforestry components and vegetation structures of homegardens

4.9.1 Components of the system

Homegardens in the study areas were found to grow fruits and other perennial trees suitably combined in an agroforestry approach in space and or time with annual and perennial crops while they also provide space for animal raising. Altogether, taking into account all higher life forms (inclusive of fruit trees) the plant community in homegardens composed of 101 species in a total area of 64.53 hectares of 150 gardens. The majorities of these species occur in tree or shrub life forms.

Apart from fruit trees, the tree component consists of live fences, cash generating species, wild fruit bearing species, other multipurpose trees and shrubs and parasitic plants (Appendix 2). In total, 46 species of trees were found grown in gardens over the study sites. Interestingly, though primarily for non-fruit utilities some 45.8% of the households were found to retain wild fruit bearing species in their gardens. Accordingly, seven species of wild edible fruit trees were recorded of which the most frequently encountered being *C. africana* (62.7%) followed by *S. guineense* (11.3 %). The latter is the only species, apart it's other uses, intentionally retained for its fruits. Some of these wild fruit bearing species are highly localized; for instance, *D. mespiliformis* at Andassa and *V. volkensii* at Zeghe and do not feature elsewhere.

Three important cash generating shrubs are widely grown: coffee, hop (*R. prinoides*) and chat (*C. edulis*) and to some extent a perennial crop sugar cane that occur in 63.3%, 41.3%, 37.3% and 14.7% of the gardens in that order. Arabica coffee has its home in Ethiopia and is a leading export commodity that also used in every home on a daily basis. Similarly, the stimulant crop, chat, is widely used especially by the urbanites and has both domestic and export markets. Hop, locally known as"*Gesho*" is the main ingredient for brewing local drinks that has also a higher domestic market.

At their limits, most gardens are fenced either by live or dead plants (dead wood thorn or wood) or by stone wall to taking care of against domestic and wild animals as well as thieves. In total, 71.4% of gardens (N=147) were found fenced of which 82.9% are fenced by live plants. The most widely used live fence plants are *Justicia schimperiana, Capparis tomentosa* and *Cassia* spp. Besides, among fruit species guava is commonly used as a live fence at Andassa area. A peculiar system encountered at Zeghe was the use of trenches around their gardens to ward off wild animals and insect pests.

Homegardens did also house more than 22 species of annual and biennial food and other crops: field crops, vegetables, spices, aromatic plants, medicinal plants and ornamentals.

The type and extent of crops grown vary depending on location. In general, except at Zeghe, maize and rapeseed are universally grown in the homegardens the later of which is used for both its green leaves and seeds. In addition, some ten species of spice and aromatic species were recorded, the most common being *Ocimum* species, Palmarosa grass, *Ruta chalepensis* and *Artemisia absinthium*. Ornamentals mainly roses, Dahlia, marigold, etc. were also infrequently recorded.

Domestic animals as cattle, sheep and goats, horse, mule and donkey, poultry and apiculture are important components of homestead agroforestry. Poultry are universally available except at Zeghe where it occurs at low frequency in the later for the wild animal foes. Besides, except a few sheep, both large animals and goats are totally missing at Zeghe while bees are better reared.

Generally, based upon the dominant crop and or tree enterprise upon which garden production based, gardens of the study area can be distinguished into three major prototypes.

Food crops-based: this system is represented by gardens at Wangedam, Robit, Wogelsa, Woinma and Arbayitu sites. Maize is the dominant crop within which or separated by space fruits are grown. Also, chat is the major perennial cash crop especially at Robit while hot pepper dominates both the Arbayitu and Woinma homesteads.

Coffee-based: these gardens are typical of Zeghe site where coffee occurs in almost all gardens and appears 'key' for the management of the homegarden ecosystem. Zeghe is a forested peninsula in Lake Tana. Its undifferentiated afromontane forest is believed artificial and dates back to 13th century to which coffee and lime were initially introduced. The Zeghe gardens have some semblance to the Chagga homegardens of Tanzania where people clear unwanted trees and retain important ones and make a supplementary planting of coffee, fruits and hop. Annual crops are entirely missing in the system as they cannot stand shade or wild animals damage and because oxen-based farming is absent. Hence, fruit intercropping is done with only shade trees, coffee and hop and in a few instances with root spices like ginger in the lowest storey. Unlike all other sites growing of chat is also absent at Zeghe for religious taboos as well as its inability to grow under the heavy shade conditions understorey.

Sugar cane-based: these gardens are available mostly at Andassa area and to some extent at Wangedam. In these gardens, water logging tolerant crops like guava are grown with sugarcane either around borders or intersperse within sugarcane field or on a clear zone of their own.

4.9.2 Dynamism of agroforestry components

In gardens, the diversity of annual crops and to a certain extent the animal component appears very dynamic depending on location and season. Some vegetables like pumpkins and gourds, potatoes, seed spices and maize are very common during rainy season while head cabbage, carrot, beetroot etc., dominate the dry season under irrigation. Crops like garlic, pepper, potato, shallot, leafy and root spices and less frequently maize are grown in both seasons. The growing frequency of annuals does also vary by location mainly depending on water and market availability. In areas like Wangedam where homestead production is based at both rain and supplemental irrigation, vegetables are grown double, triple or more times per annum while in areas that are dependent entirely on rain - fed production annuals are grown only once.

Sometimes the animal component also reduces depending on season. For instance, during rainy season when most farms are cropped and animals need to be guarded, the frequency of their stay in and around homesteads appears high. During the dry season where animal herds are let to graze freely far - off homesteads their frequency of stay declines. Similarly, chicken number reduces during the rainy season for the wild animal foes and at times of temperature rise because of a decline in hatchability. Also, during public holidays where several chicken, sheep and goats are mass slaughtered their number declines in homegardens.

On the other hand, the tree component especially the fruit trees show a relative permanency. If at all they change, that happens only at the time of establishment, aging, during tree management practices like thinning or cutting. In general, the overall garden diversity peaks in the rainy season especially June to September and declines during dry seasons around December to February.

4.9.3 Incompatibility among agroforestry components

As there are complementarities in agroforestry components, there are also cases where these components appear antagonistic to each other. The most noticeable negative interaction occurs between fruit and other trees with annuals in the form of shading. In this regard, 83.3% of the respondents believe a negative effect of fruit trees is shading while others attribute it to space demand. Regarding animal-plant interactions, several farmers see small animals like goats and sheep incompatible with fruit and other crops as well as apiculture. Besides, wild animals like apes, mongoose, porcupines, wild pigs and birds in the majority of cases interact negatively with fruits and other crop components as well as domestic animals.

4.9.4 Planting pattern and intercropping of fruit trees

The planting pattern of fruit trees is either in rows which the majority of sample households (47.9%) follow or mixed and haphazard. Nevertheless, in sites like Wangedam the row planting pattern was found to eventually disappear as the trees get aged. This is because of the filler planting practices in replacement of old stocks to an otherwise initially row-planted fruits. Planting pattern seems also depend on the type of fruit species. For instance, in most cases guava is planted haphazardly.

The types of fruit intercrops vary from site to site depending on climate, water access, household preferences, etc. Generally, the most common types of intercrops across sites appear to be hop, chat, coffee, maize and annual vegetables. Chat and hop are intercropped with fruit and other trees until only the canopies of the latter closes. Afterwards, for the shading effect of trees farmers have to make a difficult decision between retaining fruit trees and cash crops, especially chat. This is not a major problem with coffee since it is normally grown under the shades of fruits and other trees.

4.9.5 Garden vegetation structure

4.9.5.1 Horizontal management zones

The different components of the agroforestry system in homestead plots tend to occupy a certain position outwards from the centre of the house. Half of the total sample gardens (50.4%), especially those at Robit (68.4%), Wogelsa (52.9%), Zeghe (70%) and Woinma (60%) appear to grow fruit trees in differentiated zones. Overall, depending on the location and household's management strategies, the horizontal structure consists of upto three different sections with no clear demarcation in between. The first zone, which is next to a house, is devoted to small annuals like bulb crops, leafy vegetables, spices and ornamentals and raising poultry, beehive keeping, as well as, small animals. This zone also includes water wells that are used a source of water for plants, as well as, drinking. The second zone is used for growing perennial plants. Here, primarily coffee, hop and chat, medium fruit trees like citrus, guava and papaya, as well as, other useful trees as castor bean are grown circumvented with large volume fruit trees as avocado and mango. The third section, in the outlying fields, consists of mostly annual crops like maize and potato. In most cases, the third zone links the homestead and main farm and quite often demarcated by eucalypt woodlots and other trees. Livestock, both small and large ones are also integral part of the system in any of these zones while free roaming poultry are mainly in the first zone.

4.9.5.2 Vertical stratification

Some of the well developed homegardens follow more or less a multi-layered canopy arrangement the vertical structure of which generally arranged in up to four levels, which is mainly evident during the time where the diversity is maximum, that is during rainy season. The first layer houses under ground yielding plants like onions, ginger, turmeric, etc. and herbaceous crops of under a height of about 1m such as pumpkins, leafy vegetables, spices, medicinal plants and ornamentals. The second layer of upto about 5 m high consists of annual crops like maize, rapeseeds and shrubs like chat, sugar cane, hop and coffee. In the third layer, within about 10 m height appear many of the fruits like bananas, papaya, mango, guava, avocado, citrus and peach. In the uppermost (fourth) layer, trees of above 8 m height such as eucalypt and several shade tree species, large sized fruits and some wild fruit tree species are grown. However, depending on the location and garden the number of layers may range from as few as only one, (for instance only fruits of a single cohort) to as high as four or even more. The vertical layer also depends on the age of components and season. Hence, except some perennial species, the lower layers might completely be missing during the dry season.

4.10 Fruit species composition, richness and diversity of homegardens

4.10.1 Species richness, density and frequency

Based on 150 homegardens of a total area of 64.5 hectares, the number of fruit tree species came out to be 15 that are represented by ten genera and nine families. Citrus and Rutaceae respectively emerged the most dominant genus and family to which 40% and 46.7 % of the species in that order are belonged to (Table 4.22). Eight families are represented each by a single species. Besides, one liana species, *Passiflora edulis* Sims., was intercepted in a few gardens.On a site basis, Andassa registered the least number of species while Wangedam and Arbayitu at par recorded the highest (Table 4.23.)

As can be seen in table 4.23, some species are ubiquitous and thus occur across the study sites while others are site specific. In total, six species (guava, papaya, mango, avocado, banana and sweet orange) were recorded across all sites. At the other end of the spectrum, pomegranate and casimiroa were each recorded in a single site.

Table 4.21: List of fruit species recorded in homegardens across sites

Botanical name	Common name	Family name
Annona squamosa L.	Custard apple	Annonaceae
Carica papaya L.	Papaya	Caricaceae
Casimiroa edulis LaLalave & Lex	White sapote	Rutaceae
Citrus aurantifolia (Christm)Swingle	Lime	Rutaceae
Citrus aurantium L.	Sour orange	Rutaceae
Citrus limon B.	Lemon	Rutaceae
Citrus reticulata L.	Mandarin	Rutaceae
Citrus sinensis (L) Osbeck	Sweet Orange	Rutaceae
Citrus medica (L.) Burm.f.	Citron	Rutaceae
Mangifera indica L.	Mango	Anacardiaceae
Musa Xparadisiaca L.	Banana	Musaceae
Persea americana Mill.	Avocado	Lauraceae
Prunus persica (L.) Batsch	Peach	Rosaceae
Psidium guajava L.	Guava	Myrtaceae
Punica granatum L.	Pomegranate	Punicaceae

Table 4.22: Fruit species occurrence in homegardens by site ("+" = present "-" = absent)

Site/Species	Guava	Papaya	Mango	Avocado	Banana	Sweet orange	Lime	Mandarin	Citron	Sour Orange	Peach	Casimiroa	Custard apple	Lemon	Pomegranate
Andassa	+	+	+	+	+	+	+	-	-	-	-	-	-	-	-
Robit	+	+	+	+	+	+	+	-	-	-	-	-	-	-	+
Wogelsa	+	+	+	+	+	+	+	+	+	+	-	-	-	-	-
Zeghe	+	+	+	+	+	+	+	+	+	+	-	-	-	+	-
Wangedam	+	+	+	+	+	+	+	+	+	+	+	-	+	+	-
Woinma	+	+	+	+	+	+	-	-	-	-	+	-	+	+	-
Arbayitu	+	+	+	+	+	+	-	+	+	+	+	+	+	+	-

The average fruit species per garden of all sites was 5.1 and ranged from as low as one to as high as 13 species, six being the most frequent (Figure 4.24). Similarly, comparison of number of species per a standard 100 m^2 area revealed that the mean number of species across all sites (N=147) is only 0.2 which is equivalent to 20 species per hectare.

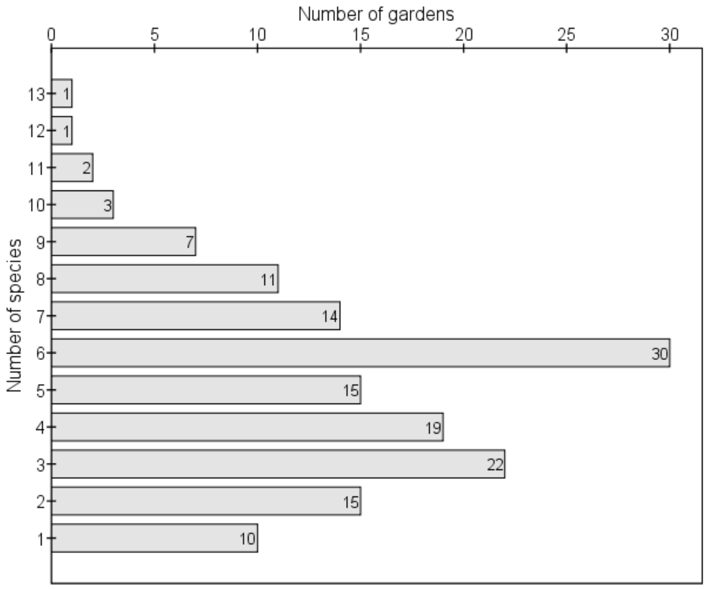


Figure 4.24: Fruit species frequency of gardens

Table 4.23: Fruit species richness and density in homegardens by site

Parameters	Andassa	Robit	Wogelsa	Zeghe	Wangedam	Woinma	Arbayitu
Sample size (N)	29	19	19	20	25	20	18
Number of species site $^{-1}$	7	8	10	11	13	9	13
Mean number of species Garden^{-1}	2.4^{A}	4.6^{B}	3.8^{ABC}	6.1^{BD}	7.7^{DE}	6.0^{BDEFG}	5.5^{BCDF}
Mean number of species 100 m^{-2}	0.05 ± 0.004^{A}	0.12 ± 0.015^{A}	0.13 ± 0.015^{A}	0.22 ± 0.054^{A}	0.51 ± 0.093^{B}	0.14 ± 0.013^{A}	0.2 ± 0.039^{A}

*Numbers with the same letter are not significantly different from each other (Bonferroni, P<0.01)

Both the mean number of fruit species and density varies significantly among sites (P<0.01). Wangedam recorded the highest number of species per garden (7.7) and differed significantly from Andassa, Robit and Wogelsa. Gardens at Andassa recorded a significantly lower mean number of species (2.4) compared to all other sites but Wogelsa (3.8). Likewise, Andassa recorded the lowest density (0.05) while Wangedam does the highest (Table 4.24).

Figure 4.25 depicts sample-based species accumulation pattern for the total gardens and separate sites. Evidently, the curve accumulated species faster at initial stages where a combination of only seven gardens provided 75% of the total species (an average of 11.2 species). Afterwards, the species increment is less than by a unity indicating that the probability of getting new species has significantly declined.

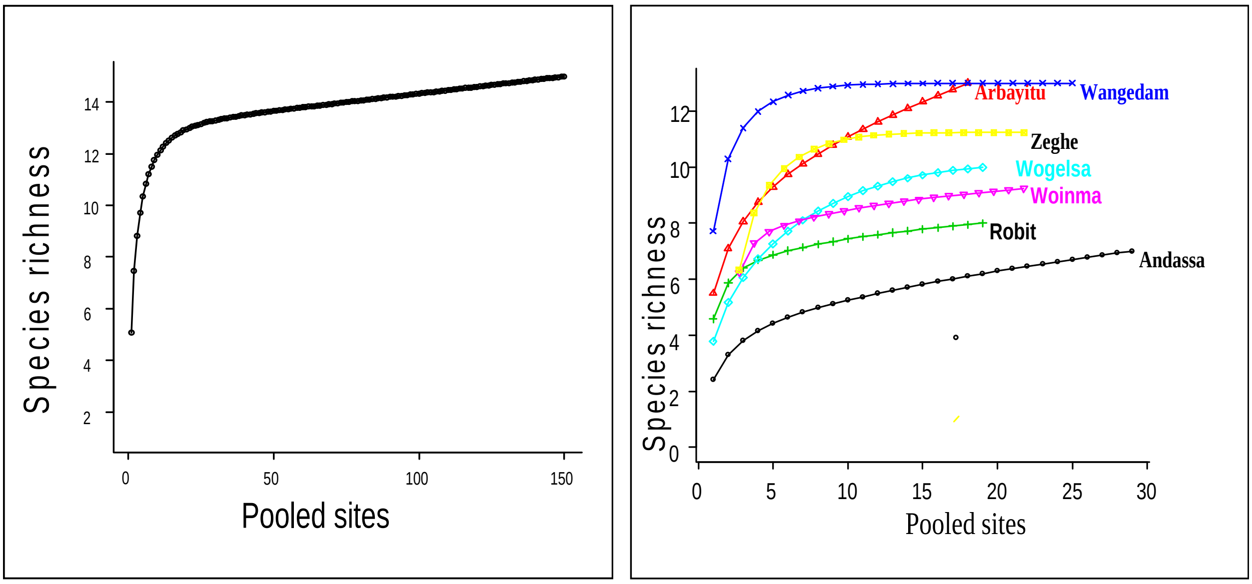


Figure 4.25: Sample- based fruit species accumulation curve for all gardens (left) and gardens of separate sites (right)

The same trend was followed in sites except that little variations are seen among sites in the accumulation patterns. For instance, when three gardens are combined, Arbayitu accumulates 67% (8.6 species) of its total number of species while Andassa does only 3.8 species. The corresponding figures for other sites are 6.4, 11.4, 6.1, 7.5 and 9.1 for Robit, Wangedam, Wogelsa, Woinma and Zeghe in that order. On the other hand, while Wangedam has initially a higher species accumulation than Arbayitu, its accumulation slowed progressively and at 18 garden combinations both sites appeared to accumulate about 13 species at par. The different rates of species accumulation provide a hint on the level of species similarities of gardens at respective locations.

Figure 4.26 illustrates the relative frequency of fruit species (N=763) and proportion of gardens growing each type of fruit species (N=150). On the whole, five species appear to be most frequently planted across gardens. These include mango, guava, avocado, papaya and banana occurring in 127 (84.7%), 103 (68.7%), 98 (65.3%), 91 (60.7%) and 73 (48.7%) gardens in that order. These same species also occurred at higher relative frequencies.

Generally, based on frequency of occurrence of species in gardens five classes of species can be distinguished:

i) *Most frequent* : species observed in >= 75% of the gardens which is only mango;

ii) *Frequent* : 51-74 % of the gardens - guava, avocado and papaya;

iii) *Moderate* : 25-50 % of the gardens - banana, lime, sweet orange and lemon;

iv) *Less frequent* : 7-24 % of the gardens - citron, sour orange, peach and mandarin;

v) *Rare:* only in 0.7 % of the gardens - casimiroa, custard apple and pomegranate.

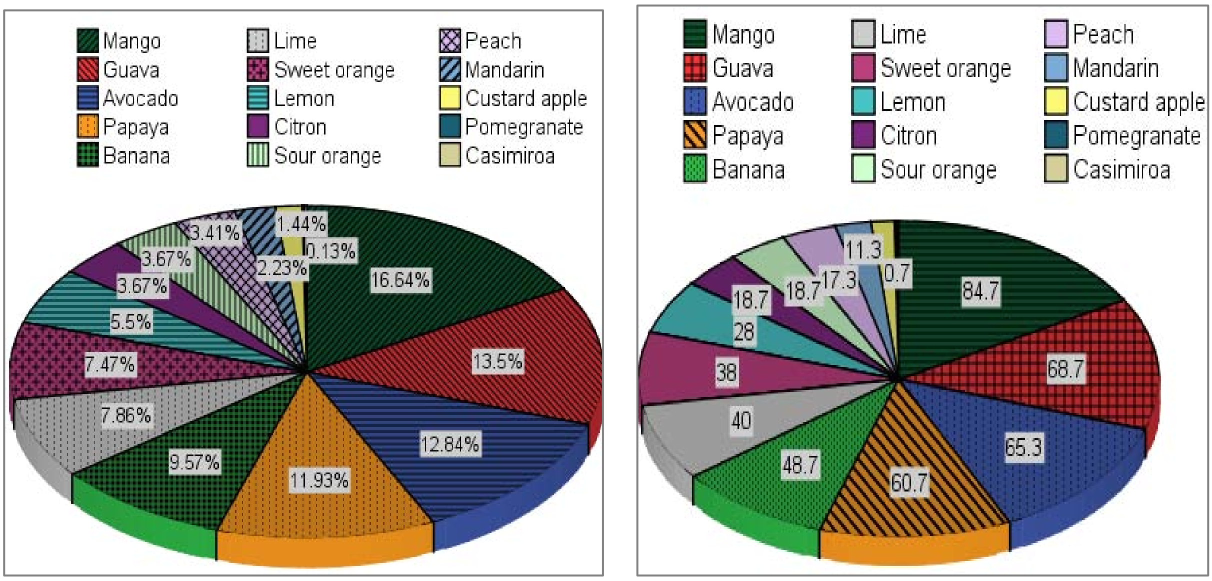


Figure 4.26: Fruit species relative frequency (Left) and percent gardens growing (right)

Nevertheless, the frequency and type of species grown by each locality somehow varies. For instance, while guava is the most frequent species grown by 9.3 in ten gardens at Andassa, mango was recorded in all gardens at both Robit and Arbayitu. Likewise, papaya was recorded in all gardens at Wogelsa and 84% of the gardens at Wangedam. Similarly, 95%

and 84% of the gardens grow lime respectively at Zeghe and Wangedam. Mango & banana were intercepted in all sample gardens at Woinma.

Table 4.24 compares the three garden size categories in terms of mean species counts and abundance as well as density. Although it did fail to achieve statistical significance, large gardens tend to have greater species richness (5.7 species) compared to medium (5.2 species) and especially small gardens (4.8 species). On the contrary, smaller gardens recorded a significantly higher species density both to medium and large gardens ($P < 0.01$).

Table 4.24: Fruit species richness and abundance by garden size (N=147)

Parameter	Garden size category			Significance level
	Small (n=69)	Medium (n=53)	Large (n=25)	
Total no. of observed species	14	13	13	
Mean no. of species garden $^{-1}$	4.77	5.21	5.68	NS
Mean no. species 100 m $^{-2}$	0.32 ± 0.041^{A}	0.11 ± 0.007^{BC}	0.06 ± 0.005^{C}	** (P<0.01)
Total no. of fruit trees per garden (range)	5 to 905	8 to 492	7 to 1613	
Mean number of fruit trees	87.62^{A}	128.30^{AB}	225.44^{B}	* (P<0.05)
Mean tree density 100 m $^{-2}$	5.83^{NS}	2.71^{NS}	2.34^{NS}	NS
Mean Shannon Index	0.99^{NS}	1.05^{NS}	1.19^{NS}	NS
Mean Evenness	0.71^{NS}	0.70^{NS}	0.66^{NS}	NS

A closer look at the identity of species grown by the different garden size categories suggested that many gardeners in large garden size category grow mango, banana, sweet orange, sour orange, lime and lemon. On the other hand, guava, papaya and mandarin are more frequent in medium sized gardens while those like papaya are more grown on small gardens than large ones (Figure 4.27).

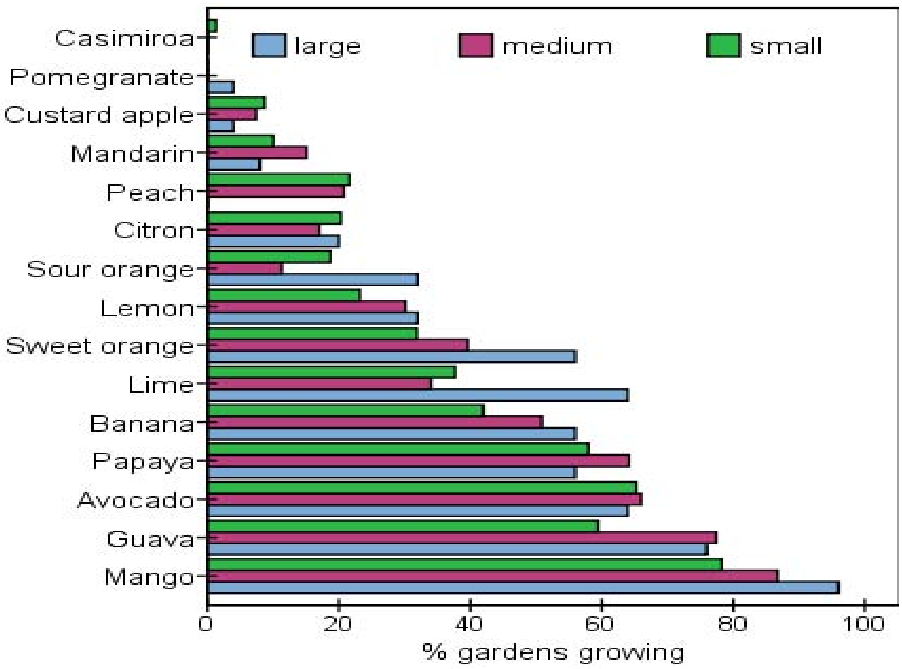


Figure 4.27: Fruit species distribution by garden size categories (N=147)

4.10.2 Comparison of species composition similarity of sites

Table 4.26 demonstrates species composition similarities and differences of sites drawing from the binary data of all fruit species and other major perennial plant species. Accordingly, by recording a relatively lower dissimilarity value, Wangedam is most similar in its species composition with Arbayitu (16%), Wogelsa (23%) and Woinma (26%). On the other hand, species composition of Zeghe is quite different from Andassa (0.51), Woinma (0.47), Arbayitu (0.45) and Wogelsa (0.44).

Table 4.25: Dissimilarity among fruit growing sites based on Sorenson distance

Site	Andassa	Robit	Wogelsa	Zeghe	Wangedam	Woinma
Robit	0.27					
Wogelsa	0.32	0.29				
Zeghe	0.51	0.44	0.36			
Wangedam	0.4	0.41	0.23	0.39		
Woinma	0.32	0.42	0.33	0.47	0.26	
Arbayitu	0.43	0.4	0.32	0.45	0.16	0.32

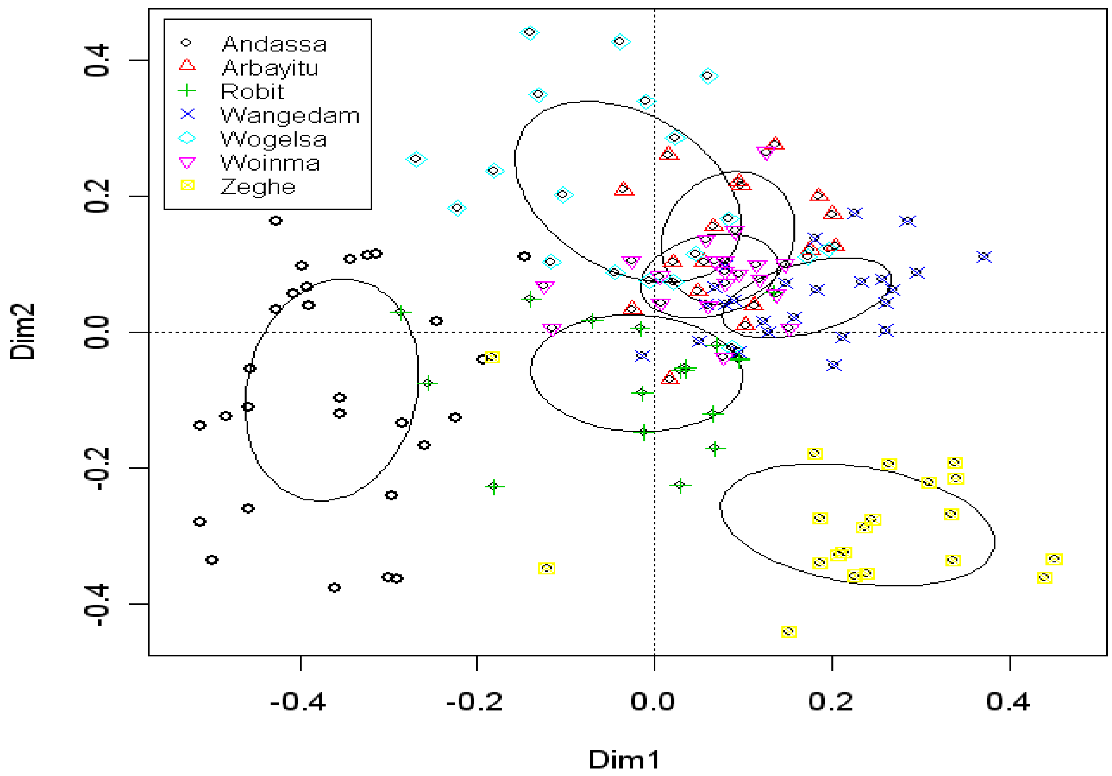


Figure 4.28: Projection of fruit growing sites and gardens in the space of the two first principal coordinates (PCoA) (Bray-Curtis distance average linkage)

Likewise, inputting the binary data of 54 species (fruit and other perennials) the ordination graph in figure 4.28 gave additional insight into the species similarities of sites. The ellipses convey where 95% of gardens of the same category are expected to occur. That is, they estimate confidence intervals for gardens of each site using the positions of gardens on the X- and Y-axes as input variables. Generally, the graph clearly shows that Zeghe, which its species constellations lying far apart, is very dissimilar in species composition to all other sites. On the other hand, all other sites but Andassa show some overlapping to each other.

All in all, based on results from ecological distance analysis and the ordination graph, as well as the dominant enterprise homegarden production based at, the seven gardens can be categorized into three major groups: (I) Andassa, (II) Wangedam, Woinma, Arbayitu, Wogelsa and Robit and (III) Zeghe. As explained under section 4.9.1 the second groups of gardens are characterized by food crops production.

4.10.3 Species diversity

4.10.3.1 Fruit tree abundance and density

The average number of fruit trees of all species (planting size) per garden of all locations (N=147) was 125.7, and ranged from as low as five to as high as 1613 trees with a median value of 59. As shown in table 4.27, the mean number of fruits per garden per locality ranges between 26 for Zeghe and 246 for Woinma, which the difference is statistically highly significant ($P<0.01$). Next to Zeghe, Wogelsa and Andassa recorded a lower than average number of fruits per garden. Woinma is significantly higher in mean number of fruits per garden than Zeghe. The average number of trees per 100 m^{-2} appeared to be 4.1 (410 trees ha^{-1}) and ranged from 0.09 to 90.5 with a median value of two. At site level, it ranged from 0.89 at Zeghe to 10.74 at Wangedam where the latter recorded a significantly higher density to all other sites ($P<0.01$).

Compared by land size category, the three garden size categories appeared to significantly differ with respect to mean species abundance per garden ($P<0.05$). Number of trees progressively increased from small to large gardens. Accordingly, small gardens possess significantly lower number of trees compared to large gardens while medium gardens failed to differ from both small and large gardens (Table 4.25). However, though it did not bear statistical significance, the number of trees 100 m^{-2} tends to decrease progressively as one goes from small to large gardens. In terms of average species abundance fruits like banana are most abundant in large than medium and small size gardens while guava is equally abundant in small and large gardens. This seems partly related to tree robustness and garden plot size.

Table 4.26: Fruit species diversity and abundance of homegardens by site

Parameters	Andassa	Robit	Wogelsa	Zeghe	Wangedam	Woinma	Arbayitu
Shannon diversity index	0.92	1.5	1.35	2.21	1.41	1.29	1.27
Evenness	0.36	0.56	0.39	0.83	0.31	0.41	0.28
Proportion of dominant species	0.67	0.44	0.56	0.22	0.64	0.57	0.63
Mean number of fruit trees $garden^{-1}$	94.66^{AB}	133.79^{AB}	58.23^{AB}	26.05^{A}	154.84^{AB}	246.35^{B}	184.27^{AB}
Mean number of fruit trees 100 m^{-2}	2.16^{A}	2.46^{A}	1.90^{A}	0.89^{A}	10.74^{B}	5.61^{A}	4.02^{A}

4.10.3.2 Species diversity pattern

As is evident from table 4.28, only few species are recorded at a higher relative abundance across locations. These include banana (40.6%), mango (16.9%), guava (15.0%), avocado (10.9%) and papaya (9.1%) that collectively make up 92.6% of all individuals of all species.

Table 4.27: Fruit species relative abundance and density in homegardens

Species	Abundance	Proportion (%)	Mean number of fruit trees garden^{-1}
Banana	7595	40.61	50.63
Mango	3166	16.93	21.11
Guava	2801	14.98	18.67
Avocado	2055	10.99	13.7
Papaya	1701	9.09	11.34
Sweet orange	615	3.29	4.1
Lime	200	1.07	1.33
Lemon	158	0.84	1.05
Peach	117	0.63	0.78
Sour orange	113	0.6	0.75
Citron	96	0.51	0.64
Custard apple	42	0.22	0.28
Mandarin	41	0.22	0.27
Casimiroa	3	0.02	0.02
Pomegranate	1	0.01	0.01

Likewise, as shown by the rank-abundance distribution curves of individual sites in figure 4.29, except at Zeghe all sites follow similar pattern of few species dominance while most other species occur at a relatively low abundance. Obviously, this also means that except at Zeghe species are unevenly distributed. Figure 4.30 further depicts both the identities and proportion of fruit trees of each species per garden by site. Apparently, banana is most abundant species at Wangedam, Woinma and Arbayitu. Likewise, guava, avocado and papaya in that order occur at higher abundance at Andassa, Robit and Wogelsa.

The Shannon diversity index for the total gardens of all sites (N=150) was calculated at 1.73 (63.8 % of the maximum possible diversity, 2.71) and ranges from zero to 2.02 with an average value of 1.05. On individual site basis, it ranged from 0.92 at Andassa to 2.21 at Zeghe suggesting that the two sites are least and highest in species diversity (Table 4.27).

Similarly, figures for evenness statistics showed a wide range (0.18-1.0) among homegardens with a mean value of 0.69. When all gardens are taken as a unit, the evenness index appears to be 0.38. At site level, evenness ranged from 0.28 at Arbayitu to 0.83 at

Zeghe indicating that species are more evenly distributed at the latter than the former. However, comparison of species diversity of gardens on land size category basis turns out to be statistically non-significant (Table 4.25).

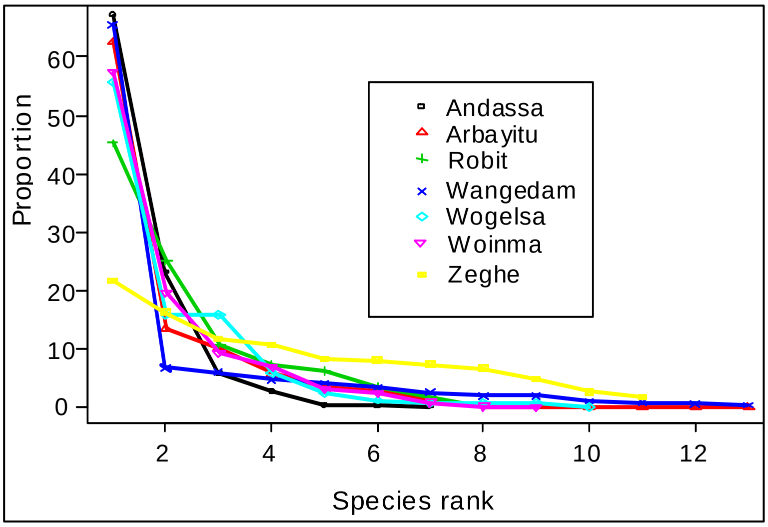


Figure 4.29: Proportion-based rank-abundance curve of homegarden fruits by site

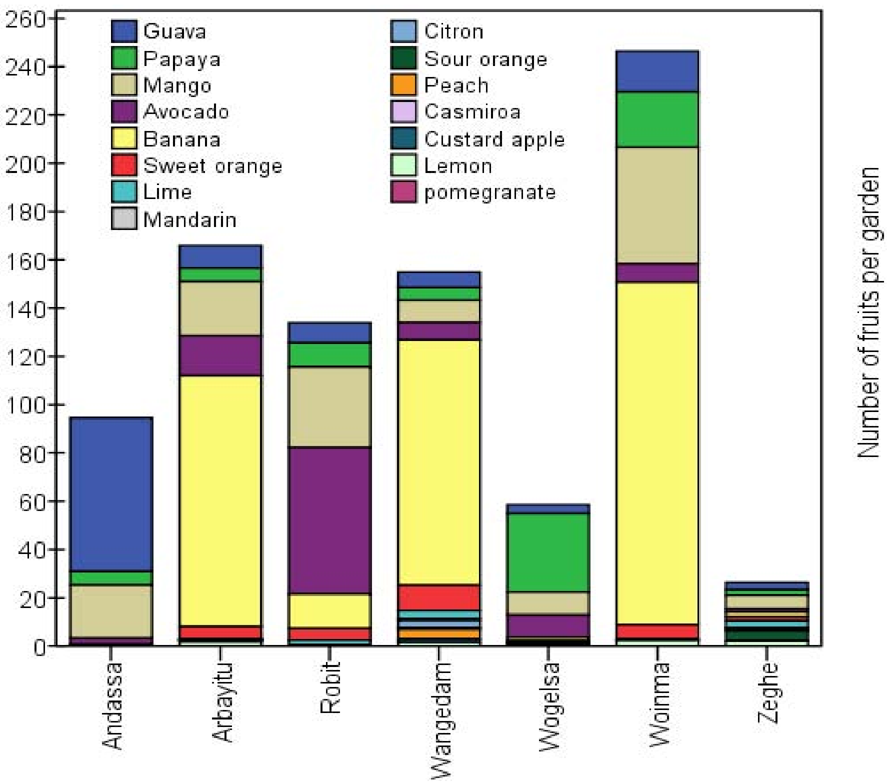


Figure 4.30: Mean number of fruit trees per homegarden by site

4.10.3.3 Ranking of sites by fruit species diversity

Comparison of fruit species diversity among sites based on Rényi Diversity Profiles (Figure 4.31) revealed that most of the sites can not be discretely ordered in species diversity. Noticeably, for its lowest profile Andassa is a site with the lowest species diversity. By the same token, Zeghe with its consistently higher profile above most of the sites, except Wangedam and Arbayitu, appears to be a site of highest species diversity. The figure further hints out that Zeghe and Andassa by recording the highest and lowest values at alpha infinity correspond to higher and lower species evenness, respectively.

Species richness aside, evenness of sites is directly illustrated by the Rényi evenness profiles on the right side graph in figure 4.31. In this case, again Zeghe laying above all other sites and taking a slightly horizontal position relative to the X-axis it appears to be the most even site followed by Robit. At the other extreme, for its' steeply curve Arbayitu tends to be least species even of all sites except Wangedam.

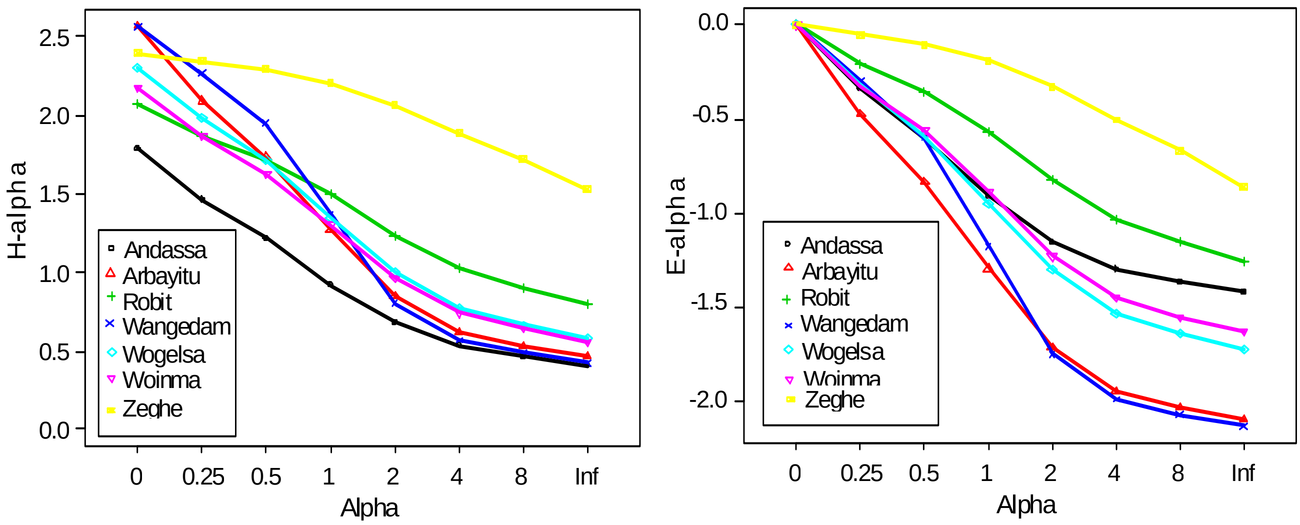


Figure 4.31: Rényi diversity (left) and Evenness (right) profiles for garden fruits of individual sites

4.10.4 Species and varietal preferences and perceptions of growers

Informants' species preferences suggest that mango, papaya, guava, avocado and sweet orange with informant frequency of 31.3%, 25%, 18.8%, 10.4% and 6.3% (N=70) are the most sought-after fruit species across locations. Nevertheless, species preferences vary from site to site. For instance, guava was singled-out as the most adorned fruit by 90% of the respondents at Andassa which they reasoned out for its market value, disease resistance and adaptability in the water-logged growing conditions.

Similarly, the majority of informants at Robit, Woinma and Arbayitu preferred mango while at Zeghe mango and orange were rated equally. Papaya was most favorite fruit to Wogelsa informants for its ability to grow under rain-fed condition, its productivity, continuous production and marketability. Quite the opposite, papaya is least preferred species at Woinma for its low price and bird damage problem. This is clearly seen by the dominance of old stocks and absence of seedlings and juveniles in most Woinma gardens. For these reasons, reportedly farmers these days decline to receive papaya seedlings from DARD. Avocado is the most favorite fruit at Wangedam partly for its climatic suitability. Generally, except at Wangedam, mango appears the most favorite fruit across the study sites.

Moreover, farmers grow several botanically unidentified varieties, which they identify them their own way by relating to their morphological characteristics, of which they prefer certain types over the others. For instance, red flesh varieties are preferred to white types in guava as they are claimed to grow fast, are firm and fleshy, less susceptible to worms, best for juice making and have a good market value. Similarly, in mango the red varieties are preferred for their productivity, marketability and earliness while in avocado necked types are most hunted.

Nevertheless, from the study it was evident that the majority of fruit growers are not satisfied with the species (76.7%) and varieties (71.4%) they are growing and want to change them. The need for improved and grafted varieties (91%), unaffordable water demand of some fruit species, low marketability and fruit drop appear to be among the major motivations for species and varietal changes. Besides, species and varietal changes are driven by other external forces. For instance, damage from wild animals is forcing several growers to shift to less attacked or immune species or to completely defer fruits in favor of other crops.

The majority of growers are generally in a bad need of grafted varieties of orange (33.3%) while several others want orange and mango (8.3%) and avocado and guava (4.2%). Unfortunately, however, despite their great demand and keen interests the majority of informants (70.2%) could not get the fruit species and attributes they liked to have.

4.10.5 Factors affecting fruit species richness, abundance and diversity

Table 4.29 furnishes the relationships between species richness and a number of explanatory covariates. The number of species per garden appears to positively correlate with the age of the household head and years of heading, training, children number, garden distance from road and altitude. On the other hand, the number of species is inversely related with garden distance from marketing center and residence. Nevertheless, only a few of these factors: training, altitude, and garden distance to market and residence emerged to pose strong influence on species richness (Table 4.30). Overall, household heads who acquired horticulture related training tend to have more number of species to those who did not have access to. Within altitudinal range of 1600-2040m ASL, gardens situated at relatively higher altitudes have more number of species to those in the lower altitudes. Of course, this is well supported by a relatively greater number of species at Wangedam (thirteen) and Zeghe (eleven) both of which lie at a relatively higher altitudes compared to sites in the lower altitudes, Andassa (seven) and Woinma (nine). Besides, far-off marketing center and residence gardens tend to have a lower number of species.

Albeit weak, fruit tree number was found to favorably related with the number of species, garden size, gender of the household head and number of children while it has an inverse relationship with market distance (Table 4.29). Except with children number, all of these factors have significant contribution to variations in species abundance (Table 4.30). Generally, as clearly shown in figure 4.32, male-headed households found to have significantly higher number of fruit trees than female-headed households (χ^2=17.28, P<0.00).

Table 4.28: Correlation of species richness and abundance with household and physical features of gardens (Pearson product-moment correlation coefficient)

Variables	Number of species	Number of fruits	Gender	Age of HH head	Number of years head	Number of children	House type	Extension contact	Training	Education level	Garden size	Altitude	Distance to market	Distance to road	Distance to water
No. fruits	.238**														
Gender	0.118	.171*													
Age of Household head	.234**	-0.027	0.125												
No. of years head	.317**	-0.014	-0.083	.825**											
No. of children	.207*	.173*	0.101	.331**	.300**										
House type	0.11	-0.047	.189*	0.135	0.116	0.12									
Extension contact	0.083	0.156	0.08	-0.072	-0.05	0.065	-0.044								
Training	.193*	0.089	-0.003	0.041	0.077	.165*	0.147	.194*							
Education level	-0.003	0.084	0.139	-.403**	-.336**	-0.061	0.009	-0.052	-0.003						
Garden size	0.068	.224**	0.049	0.048	0.006	0.105	0.159	-0.073	.163*	.162*					
Altitude	.369**	-0.102	-0.058	-0.026	.178*	-0.078	-0.033	0.106	0.023	-0.064	-.205*				
Distance to market	-.333**	-.301**	-0.147	0.012	-0.024	-0.089	-0.046	-.559**	-0.153	-0.002	.216**	-0.049			
Distance to road	.219**	0.061	0.129	.213**	0.159	0.128	0.008	.179*	-0.039	-0.046	0.035	-0.052	-.217**		
Distance to water	0.106	0.09	-0.065	0.141	0.044	.166*	-0.051	-0.016	0.129	-0.076	.293**	-.461**	-0.004	0.074	
Garden distance to a house	-.385**	-0.1	-0.037	-.231**	-.258**	-.207*	0.121	-0.146	0.153	.189*	.276**	-.196*	0.135	-.219**	-0.098

Note: * *,   *= Correlation is significant at the 0.01 and 0.05 level in that order

It was also disclosed that the larger the garden size the more number of trees it houses (χ^2=

11.93, P<0.018). For instance, some 43.5 % of the small gardens composed of 40 or less number of trees while 44% of the large gardens contain more than 100 trees per garden. Of course, land shortage was rated first by several informants (38.3%) to affecting the number of fruit trees in gardens. From the regression analysis, it was also evident that gardens close-by a marketing center possess greater number of fruit trees.

Furthermore, as judged by the Shannon diversity index trained household heads tend to maintain higher species diversity as was the case with species richness. Also, gardens located far away from road maintain greater species diversity while those situated far from residences recorded low diversity. Again, diversity tends to increase as the altitude gets higher. Surprisingly, access to extension service has a negative relationship with species diversity. Species evenness increased as garden distance to marketing center lengthened.

Table 4.29: Factors affecting species richness (quasi-Poisson GLM), abundance (negative binomial GLM) and diversity of fruits in homegardens

Variables	Significance level of coefficients			
	Species richness	Species abundance	Shannon Diversity Index	Evenness
Age	ns		ns	ns
Gender		***	ns	ns
Number of years head	ns		ns	ns
Number of children	ns	ns	ns	ns
Training	*		***	ns
Extension contact			**	ns
Distance to market	**	***	ns	***
Distance to road	ns		***	ns
Distance from home	***		*	ns
Altitude	***		**	ns
Garden size		***		
Dispersion parameter	0.76	1.36	0.19	0.05
Deviance explained (%)	40.94	38.65	26.74	31.08

Note: *, **, ***, significant at 0.5, 0.01 and 0.001; ns = not significant

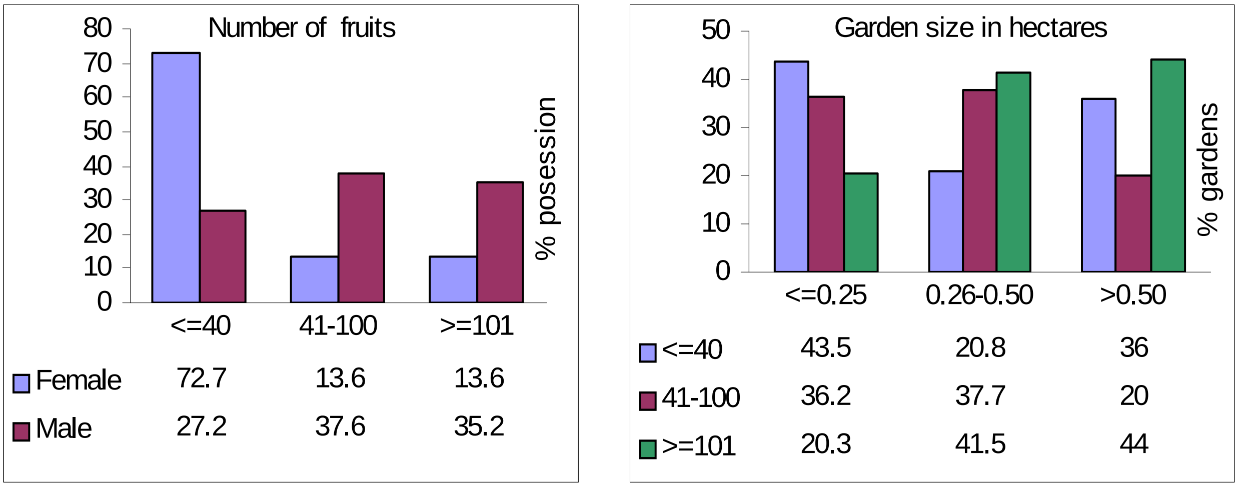


Figure 4.32: Influence of gender (left) and homegarden plot size (right) on garden fruit species abundance

4.11 Planting material supply, propagation and agro-techniques in gardens

4.11.1 Nurseries, planting material supply and propagation

Generally, two categories of horticultural nurseries were identified in fruit growing areas. One is a government nursery that usually occurs at a frequency of one at a district level and catering peoples' needs within and outside the district. Accordingly, three government nurseries are available in the three study districts located at Meshenti in Bahir Dar Zuria, Fanda in Bure and Finoteselam in Jabitehnan *Woreda*. These nurseries raise and distribute more or less similar species which are dominantly mango, avocado, papaya and guava (Appendix 4). Undoubtedly, the presence of these nurseries have become a trigger for many people in their environs to enter into fruit production as can demonstrably be shown in the Bure and Finoteselam areas. The second types of nurseries are the very scanty temporary farmers' nurseries that mainly outfit the needs of their owners. Such nurseries are also recognized and supported by DARD. However, they are not in a position to sell extra seedlings primarily for their low capacity as they are taken up as a tangential business and because government nurseries discourage them by supplying seedlings free or at very cheap price to growers. Neither community nor large-scale private company nurseries were encountered to operating in the study areas.

As a result, the sources of planting material for fruit growing comes either from own source, DARD, purchase or barter and wildlings. The majority (upwards 47%) get planting materials from DARD, if not freely, at a very cheap price like 0.5 Ethiopian cents per mango and 0.15 cents per a papaya seedling. In addition, DARD provides plastic for potting which is also in most cases supplied freely. Reportedly, NGOs like Care Zeghe and SOS were once active in supplying seedlings to growers at Zeghe and at Andassa, respectively. However, this has now discontinued. Hence, planting material supply is generally far short of growers demand. This is also well felt by the majority of sample informants (69.7%), which they complained that their demands are not yet satisfied. Of course, 8.5% of the informants reasoned out planting material shortage a major factor hindering not to plant fruit trees more than they have now. This situation was also well consented by the DARD offices which they reasoned out for budgetary constraints.

Fruit propagation is undertaken from either seeds, vegetatively or from natural regenerants. Some 25% of the sample households resort to seeds, 27.1% grafted materials, 37.5% both of these methods and 2.1% use natural regenerants as a planting material to start fruit growing. Grafted seedlings are in most cases sourced from DARD nurseries. The only attempt of farmers` self grafting was recorded at Andassa where a few farmers managed to graft orange scions onto a lime root stock for their own consumption while sometimes they extend services to other farmers. Seen at species level, mango, guava and avocado are generally propagated from seeds by farmers. Guava and to some extent mango are also widely propagated from wildlings which essentially originate from seeds. Although most growers receive planting material from DARD, these are still raised from seedlings collected from unknown source, sometimes purchased and other times collected from juice shops or from unknown mother stocks. As a result, the quality of planting material by and large remains mediocre.

4.11.2 Agro-techniques and fruit tree management practices

Notwithstanding weak, some 87.2% of the sample households were found to have access to extension service. Hence, by way of training and advisory services, field days, exchange visits, demonstration plots, etc. DARD remains a major source of knowledge for the majority of sample farmers (31.4%). Additional knowledge for fruit gardening comes from either own source, relatives or neighbors or role model people in the community. The trend is similar in all sites except at Zeghe where there is a relatively minimal extension support (60%) and for which growers have to resort to their own sources. Nevertheless, other than minimal cultivation and weeding, most informants do not follow proper cultural management practice. A few of them (4.2%) assert to practice mulching except at Zeghe which this practice is entirely absent for the high litter fall that keeps the soil moist and fertile. Too often while field crops are sown by ploughing fruits plots are dug manually using a hoe.

Neither is tree management practice well developed in the study areas. Only 2.1% of the households practice grafting, 8.3% pruning and 4.2% a form of partial pollarding or lopping. Again, none of these are practiced at Zeghe site. Tree spacing tends to be optimal with a little higher than half of the gardeners (53.2%, N=124), is crowded on forty-five gardens (36.3%) and spacious on 13 (10.5%) of the gardens. Most crowded trees were recorded at Andassa (44.8% gardens). At initial planting farmers generally consider a tree-to-tree spacing of about 7-8 meters for mango, 8-10 meters for avocado and 6 meter for orange. However, later intensive intercropping of both annual and perennial crops and or trees results in a far higher than optimal spacing. In addition, because of replacement planting of trees the planting pattern of several gardens has recently changed from row to mixed (66.7%) that might aggravate the spacing problem. Conversely, the positive development is, however, that some growers (8.3%) are shifting from haphazardous to a row planting pattern.

4.11.2.1 Fertility management, and disease and insect pest control

As a fertilizer source, the majority of sample households (79.2%) apply manures of different sorts: kitchen and house wastes, ash, brewery residues, charcoal, litter fall, night soil, rape cake, etc. on to their fruit gardens. In areas like Robit, especially farmers of extension contact have recently started composting while at Andassa some 14.6 % of the households apply rape cake. Again, Zeghe households do not use any form of manure because of the higher litter fall and higher soil fertility perceived at this location. Generally, except in a few instances where DAP was reported to be used as a starter fertilizer by few growers at Woinma and Wangedam, no chemical fertilizer is applied in homegardens.

Table 4.31 compares sites with respect to homegarden soil fertility status. The mean total nitrogen, available phosphorus, organic carbon, pH and CEC appeared to be 0.26%, 51.33ppm, 2.80%, 6.3 and 36 Cmolkg^{-1} soil in that order. The corresponding figures for the control plots (out side the homestead zone) were 0.19, 6.79, 2.06, 6.12 and 38.86. This suggests that the homegardens are by far fertile than arable fields especially with respect to nitrogen, phosphorus and organic carbon contents. There is also a significant difference among sites with respect to total nitrogen and pH value ($P<0.01$). Total nitrogen is significantly higher at Zeghe (0.38%) compared to Andassa (0.18%) and Wangedam (0.20%). The Wangedam (6.8) and Arbayitu (6.8) sites recorded significantly higher pH value than Wogelsa (5.8) which indicates that the latter is relatively more acidic. The Zeghe site is generally superior in total nitrogen, available phosphorus, and organic carbon with a relatively neutral pH. The soil texture of sites is clayey at Andassa, Zeghe, Wogelsa, Woinma and Arbayitu, clay loam at Wangedam and sandy clay loam at Robit.

Table 4.30: Soil fertility status of homegardens

Site	Total Nitrogen (%)	Available Phosphorus (ppm)	Organic carbon (%)	pH	CEC ($Cmol_c kg^{-1}$ soil)
Andassa	0.18**	16.95	2.3	6.3	39
Arbayitu	0.28	67.28	2.69	6.8**	35.6
Robit	0.26	55.04	2.73	6.2	32.8
Wangedam	0.20**	41.81	2.54	6.8**	31.8
Wogelsa	0.27	41.79	2.18	5.8**	36.8
Woinma	0.28	26.68	3.55	6	41.8
Zeghe	0.38**	109.75	3.63	6.4	34.2
Mean	0.26±0.01	51.33±9.96	2.80±0.16	6.33±0.09	36.00±1.46
Control	0.19**	6.79	2.06	6.1	38.86

** Significant at $P<0.01$

As regards pest and disease control, except at a few instances where pesticides are indiscriminately sprayed to fruit pests in connection to chat pest control they are not common in fruit production. Some 20.8% of the sample informants claim to apply pesticides like Diazinon and Malathion against red scale of orange and sometimes false codling moth of guava.

The study areas are rich in natural water bodies. Apart from rainfall there are ample opportunities to accessing other sources of water for fruit growing. However, at present the major sources of water for the most growers (58.5%, N=147) appears to be river-based irrigation canals which are constructed either traditionally or in modern line while some 2% use motor pumps to withdraw water from rivers. Some 10.2% of the respondents rely only on rain source, 9.5 % fetch from rivers manually while 7.5% use water wells. The majority of households at Andassa (62.1%) and Wogelsa (42.1%) and all households at Wangedam, Woinma and Arbayitu resort to furrow irrigation canals.

Accessibility and physical structure of the soil seem to bring about variations in ground water use via water wells. Evidently, because of the high water table (resulted from its location at Lake Tana shore), 52.6% of growers at Robit resort to hand dug water wells that count up to six per household and to which a pulley system is fitted to withdraw the water. By contrast, wells are very infrequent in Wogelsa partly because either it was not given a try or the soil is rocky and the water table is low. On the other hand, water wells seem not practical in areas like Andassa as the soil is deeply cracking and at Zeghe where the water table is low for its raised topography. Hence, ground water remains much unexploited in most of the study areas as a water source. Surprisingly, Zeghe peninsula is constrained by water availability for its raised site as a result of which growers depend either only on rainfall (55%) or fetching water from Lake Tana (45%). In fact, the need for supplementary irrigation is also related to water demand of the species. For instance, for its low water demand after establishment and because it's planting time coincides with the beginning of rainy season papaya is mainly produced under rainfall. This would of course be achieved at the sacrifice of yield and quality since under low moisture conditions floral sex shifts towards female sterility that result in low productivity.

4.12 Fruiting phenology, utilization and income generation in gardens

4.12.1 Fruiting calendar

Figure 4.33 clearly illustrates the fruiting calendar of some major fruit species. Obviously, species as guava, papaya and banana are available almost round the year. Looking at individual species, guava trees fruit year round with a bumper harvest from May to October after which fruiting declines progressively and become very lean around March. Similarly, papayas fruit throughout the year though they mostly fail to ripe in the main rainy season, June to August. Lime is another species that stays in fruiting for nearly nine months, from about May to January.

On the other hand, species like mango, avocado, orange and peach ripe at a narrow range of time and their fruits completely disappear during the rest of the year. Their fruiting is mainly concentrated around March in the dry season to the middle of main rainy season, June to July.

There appeared, however, slight variations among sites in the fruiting phenology of some species that can be accounted for climatic and varietal differences. For instance, guava is very variable in its fruiting phenology. While its fruiting peaks in November at Andassa it extends to January-March in other places. Likewise, red mango varieties mature early in March while white types ripe in June. Similarly, a peach variety locally known as "*Yeferenj Kok*" comes to fruiting early in January than the local peach that matures around March.

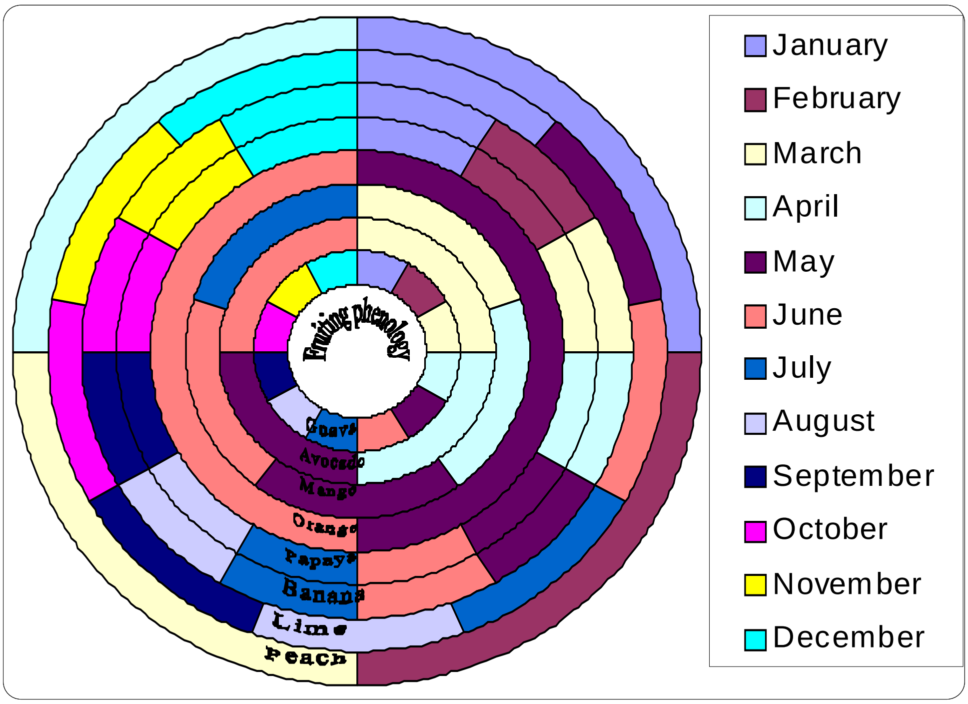


Figure 4.33: Seasonal fruiting calendar of homegarden fruits in the study areas (each circle represents fruiting season of a single species)

4.12.2 Fruit utilization and income generation

Although the majority of informants (95.8%, N=48) reported to grow fruit trees for both home consumption and selling, a good proportion of them (47.9%) further indicated that the amount consumed at home is very trifling. Some 31.3% of the informants consume up to 25% of fruit produce at home, 4.2% consume up to 50% and the rest (8.3%) use from 75% to the whole produce at home. The latter is mainly when the number of fruit trees in gardens are very few for a meaningful sale and or the fruit trees are established late so that most of the trees do not come to fruiting in synchrony. In such situations growers find fruit marketing less paying and thus they would opt to use it at home. The amount consumed at home also varies depending on the perceived value and volume of production of fruit species. For instance, in those species like guava where fruits are produced abundantly but fetch low market prices, quite a good proportion of the product tend to be used at home, whereas in relatively expensive fruits like avocado and mango greater volume of the produce is likely to go to markets for income generation. Moreover, fruits which their mode of utilization is less familiar to growers as avocado are all sold. The majority of growers (79.2%) consume fruits fresh and raw while 18.8% use both raw and by processing them into juices. Avocado fruits were reported to be used a substitute for oil and butter in stew making at Wangedam which is undoubtedly for its higher oil content.

Marketing of produce is usually done by transporting to the nearby markets and directly selling to consumers or retailers and whole sellers. To some extent, fruits are disposed to contracted clientele usually juice shops, hotels, cafeterias of higher learning institutions, hospitals, etc. In few cases, traders go directly to the producers and buy either standing fruit trees or fruits at farm gate. At times, fruits are sold by the roadside, as is the case with papaya at Robit area and lime around Bure and Finoteselam. In the later areas, it is also common to sell fruits like lime and peach to passengers in cross-region and cross-country transport vehicles.

Fruit prices are generally low and vary to some extent by site, market and most importantly season. During the study year (2006), on a kilogram basis guava was selling 0.50 to 1.5 Birr, mango 1.75 to 2.50 Birr, avocado 2.0 to 3.50 Birr, orange 2.0 Birr, papaya 0.70 to 2.00 Birr, lime 0.25 cents and a banana hand 5 to 25 Birr. It is also common to sell fruits on a number basis. For instance, with 10 Ethiopian cents, one can buy two guava fruits, one to two peach fruits, 50 lime fruits or 10 lemon fruits. Similarly, one orange sells 30-50 cents, mango 30-60 cents, avocado 50 cents, banana 10-20 cents, papaya 1.0-2.0 Birr and Custard apple 2.0 Birr.

In general, the price of all fruits on average reduces by at least 0.50 to 1.0 Birr during peak production seasons. Contributing to the low price are also poor product quality and absence of value - adding techniques. Marketed fruits are generally bruised, discolored, pest damaged, unsorted by size and ripeness. As a result, the income from fruit marketing is low and depends on season and the number of fruit trees one has. From discussions with informants, the estimated income from fruit sale ranges from as low as 50 Birr to 4200 Birr with a mean of 1078.80 Birr per household per year. Besides, most fruits remain unexploited for the lack of small - scale or commercial processing plants. For instance, lime is one of the most abundant but too unexploited species especially in the Bure and Jabi Tehnan areas that could have been processed easily into non - alcoholic drinks like Lemonade or Citric acid.

4.13 Major bottlenecks of the fruit production system

4.13.1 In the homegardens

Several bio-physical, socio-economic and cultural factors appeared to restrain the fruit production in the homegardens. Depending on the locality and fruit species, informants listed more than 21 constraints (Figure 4.34). Of which, wild animals about which people are weary of, lack of appropriate varieties, shortage of land and water, insect pests and diseases remain the most prominent.

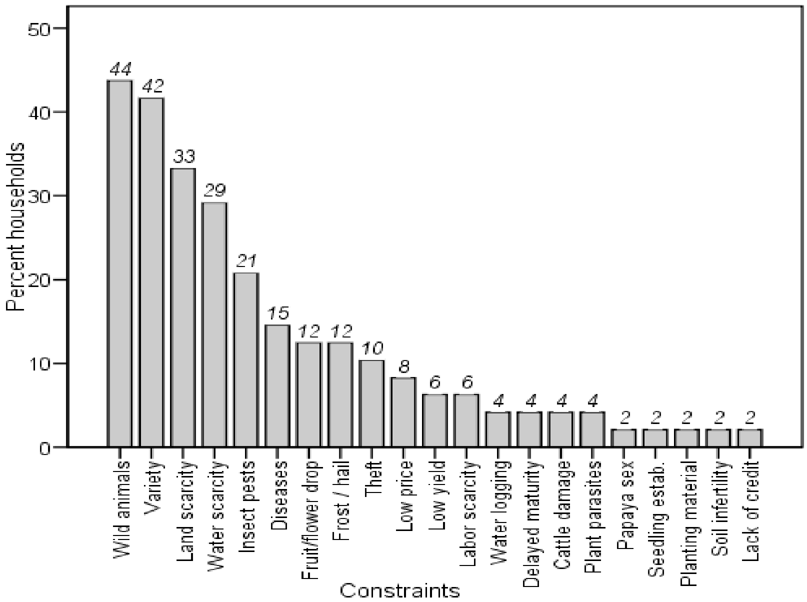


Figure 4.34: Major constraints of homegarden fruit production in the study areas

While some of the constraints like water scarcity and lack of appropriate variety are common across several sites, others are site specific. For instance, *Phaermularia angolensis* appears the major obstacle to the production of sweet orange to the level of abandonment mainly in the Jabi Tehnan area. Similarly, *Phytophtora* species are severely restricting orange production around Andassa area. Wild animals are major constraints mainly at Zeghe and Wangedam for their forest analogous ecology that gives them a safe-haven. Mistletoes are very problematic on peaches mainly at Wangedam while water logging and low soil fertility problems are more felt at Andassa. Generally, because of perceived constraints and opportunities sought for growing fruits are both at an increasing and declining trend depending on the species and locality. It seems that guava at Andassa, mango in all sites but Andassa and Wogelsa, and papaya at Wogelsa are at an increase, whereas, papaya (Andassa, Robit, Woinma and Zeghe), orange (Andassa), Avocado (Wogelsa) and local peach at Wangedam seem to be on decline.

4.13.2 The wild edible fruit system

A snapshot of the analysis of the wild edible fruits system is visualized on a rich picture in figure 4.35. At higher level of organization, internal agro-ecological, economic and socio-cultural factors hold back wild fruits development each with various specific biotic and abiotic factors.

Among biological factors, insect pests and diseases (*Ficus* spp., *Z.spina-christi, D. mespiliformis, R. abyssinica* and *Carissa* spp.), Loranthus parasite (*Z.christi*), free roaming cattle (*R. abyssinica, Rubus* spp. and *C. africana*), goats (*D. abyssinica, R. abyssinica* and *Z. christi*), wild animals (*Ziziphus* spp., *Ficus* spp*., D. mespiliformis*, *X.americana, R. abyssinica*, tamarind) appear problematic. Low pulp content is a universal phenomenon in almost all fruits while alternate bearing was reported in several species (*Z.spina-christi, Carissa* spp., *F. virosa* and *Rhus* species). Other species as *D. mespiliformis* are characteristically slow growing to come to first fruit bearing, which at informants' conservative estimate the latter species takes eight years. High pershiability of some species like *S. guineense* and seasonality of most species hinder sustainable food supply and marketing. Among physical factors, fire that is a recurrent practice at Adiarkay appears damaging to all species especially *X.americana*. Besides, recurring drought is increasingly felt to affect regeneration of species like *X. americana* while it reduces fruiting load in several others*.*

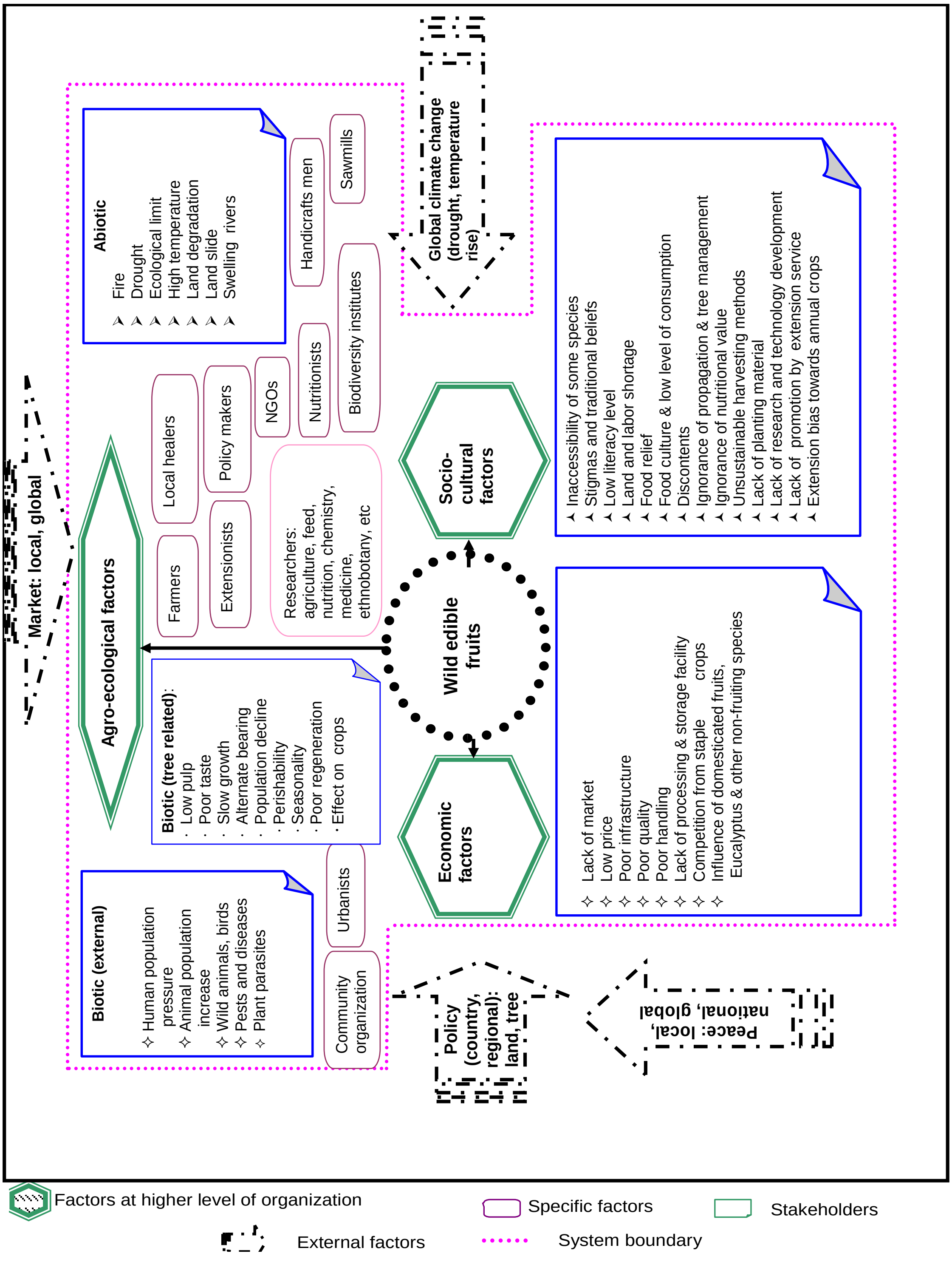
In addition, socio-economic factors as market availability and low prices are terribly discouraging wild fruits marketing. Besides, scarcities of resource endowments, e.g. land shortage, deter significantly the domestication of wild fruits.

Furthermore, culture and belief of people seem to greater extent hold back wild fruits utilization. The majority of informants attaches wild fruits low values and feel less dignified on their use or marketing. This is further aggravated by some unfounded beliefs and prejudices. For instance, with the belief that it invites thunder by hosting bad spirits tamarind growing is avoided in homesteads. Similarly, *S. guineense* trees hosting parasites are believed to have magical power for which trees are destructively cut by the Witchdoctors.

Besides, various external factors as government policies (e.g. land and tree tenure), climate change (increased temperature and drought), etc. affect the wild fruit system. Several individuals and organizations have also directly or indirectly stakes on wild fruits development. In this regard, analysis of the general situation suggested that research and operational organizations give a very low attention towards wild fruits. All these factors appear to interact either positively or negatively to influencing the wild fruits system. Hence, interventions aimed at wild fruits development may need to take into account all these components and deal in its entirety.

Figure 4.35: A rich picture visualizing the wild fruit system

Figure 4.35: A rich picture visualizing the wild fruit system



5 Discussion

5.1 Species composition, diversity and distribution of wild fruits

5.1.1 Species composition and distribution in the overall landscape

Despite the marginal environment and poor vegetation backdrop, the study areas recorded quite a good number of wild fruit bearing plant species (Table 4.1) that fall well in the range of previous area-specific inventories of good ecological background elsewhere in Ethiopia (Guinand and Dechassa 2000; Getachew et al. 2005). Concurrent with reports of Zemede and Mesfin (2001) and Kebu and Fasil (2006) most of these species occur as trees in their life forms. This sheer dominance of tree life forms could be advantageous in view of getting hold of diverse utilities especially should they are incorporated into agroforestry systems. This might also mean that fruits are more likely to be available year round (Castaneda 2004) including the dry seasons and even at times of drought. Moreover, the majority of the species are autochthonous which is useful in view of prospects of domestication as they can easily adapt, resist biotic and abiotic stresses and can be grown with a low level of input requirement.

The habitats and ecological niches of the recorded species are rather diverse. It stretches from the homesteads to the farm and grazing areas to forests and scrubs, river banks, etc., and several of them occupy multiple niches. Some species inhabit characteristically much degraded marginal sites. Such an occupation of diverse niches and adaptation to difficult conditions would provide a better advantage for the conservation of these species while it could enhance the overall productivity and stability of agro-ecosystems.

The climate of Ethiopia is mostly determined by the altitude, which dominates all aspects of land use because of its significant influence on rainfall and temperatures, which in turn dictate the dominant vegetation types prevail. Accordingly, looking at their vertical distribution wild fruit species occurred across a wide range of altitudes between 1200-3300 meters ASL, the majority of which occurring in the low to medium altitude continuum with broad overlap in between. As a result, the number of fruit bearing species significantly declined as the altitude gets higher which concurs with Stevens (1992) and Redzic (2006). This can be interpreted in view of the overall vegetation distribution pattern. Plant species richness and diversity generally lowers in communities characterized by environmental extremes than in mesic environments (Brockway 1998). Hence, the dropping temperature in the highlands especially around the Semen Mountains at sites like Debir could have restricted the occurrence of several species. Another explanation could be that the Ethiopian highlands are on the whole drier, for example, compared to East African Mountains so that they record lower number of species (Tewolde Birhan 1991). Nevertheless, while the pattern of plant diversity may be broadly related to numerous environmental factors, it is likely the result of complex interactions at multiple scales among physical and biological factors within a historical context of stochastic disturbance events (Brockway 1998). Of course, the highlands in the study areas are the most populated sites where anthropogenic factors culminated in severe land degradation and deforestation which would also have a direct bearing on wild fruit species.

As a result of stark differences among sites in elevation and climate that provide a wide array of niches for different species, the study sites appear to differ substantially in the number and type of edible species they are housing (Table 4.2). In total, sites representing lower elevations and for most part sharing overlapping ecological niches (Bermariam, Adiaregay and Kurar) recorded by far greater number of species and show greater species resemblance among them than the highland site, Debir (Table 4.2; Figure 4.3). On the other hand, Debir and Kurar appeared different from each other and from all other sites for the peculiar climatic set up of the former and geographical disjunction of the later. Generally, while the presence of inter-site differences testifies the existence of species specificity of sites, it also clues the presence of a good level of biodiversity at the level of the total landscape. Of course, a high degree of site specificity of species distribution is a phenomenon with indigenous fruits (Schreckenberg et al. 2006).

The study has additionally recorded intra-specific variations in several fruit bearing species that are expressed mainly in terms of fruit size, shape, taste, yield, etc., and other plant parts. The existence of such a natural variation is a crucial factor in efforts aimed at conservation, development and utilization of edible forest species (Okafor 1991). While the bulk of genetic variation found within tree species is accounted for provenance and tree-to-tree differences (Appiah 2003), our results suggest that variations could also arise merely from site condition differences. This can be exemplified well by *T. indica* where trees on the upper slopes tend to be small stature with small fruits to those at lower slopes. Similarly, fruit size variablities in species as *S.guineense* and *R.abyssinica* were noted to largely arise from soil fertility differences. Generally, the intra-specific diversity observed in the study underpins the need for genetic analysis to discern between genetic and phenotypic traits. Identification of genetic traits would then present an opportunity to select and develop cultivars with desirable characteristics that enhance the appeal to both the growers and the market (Leaky and Simons 1997).

5.1.2 Species diversity and frequency in the human- managed landscape

Most of the wild fruits appear to be exploited from the natural stands, which is in conformity with previous reports of Demel and Abeje (2004) who stated that in Ethiopia for most of the plants fruits are still collected from the wild. Nevertheless, albeit primarily for non-fruit utilities, farmers tolerate some wild fruit species at different niches in the realm of anthropogenic ecosystems. In fact, the practice of growing dispersed trees of different utilities in farmlands is the most dominant agroforestry practice that characterizes a large part of the Ethiopian agricultural landscape (Badege and Abdu 2003). Nonetheless, no wild fruit species has so far been brought under full domestication for the purpose of fruit production. Even most popular domesticates in several other countries like *T. indica* and *Ziziphus* spp., are mostly found feral or under semi -wild conditions.

Overall, *C.africana, F. virosa,* and *Z.spina-christi* appear to be species of high relative abundance in the working landscapes (Figure 4.5; Table 4.5) that varies by site. The inter-site differences in farm species richness seem largely governed by the overall species richness setting of the respective localities. This is because sites that recorded higher species richness in the overall landscape by and large corresponded to a better farm integration of wild edible species and higher diversity. For instance, at Bermariam where there is better vegetation cover in the natural milieu (partly for its proximity to the Waldba Monastry) so is a higher level of species integration in the agricultural landscape while the reverse is true at Debir. Thus, the more parent trees present in the natural environment the higher the probability that farmers retain more trees in their farms. More often, the diversity of wild foods declines during the conversion of complex woodland to simplified cropped land (Scoones et al. 1992). The present finding is in agreement with Degrande et al. (2006) who found a clear decrease in species diversity as access to the forest declined.

On the other hand, though the natural milieu recorded relatively higher number of species at Kurar the level of integration in the agricultural landscape is low. This can be explained by its extremely dry climate that might render it unattractive for agroforestry development (Minwuyelet 2004). In another situation, though species are available in the natural milieu they failed to be recorded in the agricultural landscapes in some localities but are in others. This was true for *T. indica*, which grows at both Adiarkay and Kurar in the natural environment, but was found in large numbers in farms at Kurar than in Adiaregay which could be ascribed to cultural and socio-economic differences of the people.

Species richness aside, tree numbers appear to be more even at Kurar and least at Dibbahir. Evenness might be strongly influenced by either biotic or abiotic factors on a local scale (Wang et al. 2003). Since Dibbahir is a transitional zone favorable for accommodating various ranges of species, the probability of some species dominating would be higher leading to uneven species composition at the total landscape level that might in turn influence the evenness of farm species and peoples preferences. Conversely, at Kurar the ability of any single or group of species to dominate in the natural milieu would be low due to the harsh climate that in turn narrows species choice of people for farm integration. This is in line with Brockway (1998) who reports a higher evenness where the climate is more severe.

Figure 5.1: ***Z. spina-christi*** **trees dispersed over harvested sorghum field near Adiarkay town**

In landscapes where alpha diversity is low and beta diversity is high, a wider distribution of species of lower frequencies would substantially increase the alpha diversity (Kindt et al. 2003). Hence, the wider gap in species richness and evenness among sites in the present case instructs the need to enhancing diversity through enriching species thin farms and distributing the species within and across sites whenever climatic conditions permit to do so and of course based on farmers interest and preferences. For instance, while its value was much talked about than its farm inclusion, *T. indica* occurs only sparingly in Adiarkay while it is common on farms in the Kurar area. It should be thus easy to increase this species on farms at Adiarkay since it has demonstrated its fitness by being available in the natural milieu and people already have appreciation and preference for it. A balance in species and trees of farms could be achieved by improving awareness of farmers to maintain even numbers of trees and balanced germplasm distributions.

From the study it is also apparent that only a few species as *C. africana* and *Z.christi* (Figure 4.8) occur with higher frequency in the agricultural landscapes. This can partly be explained by their good virtues and diverse non-fruit utilities. *Z.christi*, *C.africana* and *T. indica* are the three species which are most used in several ways by the community (Figure 4.17). More importantly, the compatibility of *C.africana* with annual crops for its low mean canopy closure and Leaf Area Index (Mulugeta et al. 2004) and less competition with crops during critical shortage of water owing to its deciduous nature (ICRAF 2008) could attract and prompt most farmers to retain it. Similarly, *Z. christi* has no negative impact on agricultural crops (Demel and Abeje 2004) and is known to improve soil quality by increasing available phosphorus and total nitrogen as well as increase yields of associative crops (Verinumbe 1993). This was also confirmed by the present study that a higher level of phosphorus was recorded in the rhizosphere of *Z. christi* trees (Table 4.14). In addition, this species was found in several instances associated with termitaria, which is a further clue of its association with soil fertility as termite mounds are known to be a source of high clay soil fraction influencing soil properties and plant nutrient contents as compared to surrounding soils (Nyamapfene 1986; Konat´e et al. 1999). Also, tamarind was found to have significantly higher soil total nitrogen and organic carbon contents within the crown projection area than outside, which could be attributed to its nitrogen fixing ability. On the other hand, a limited fitness of a species for a particular use was suggested one possible reason for the low frequencies of some species in a landscape (Kindt et al. 2003) and that the abundance of a species is only a crude reflection of its overall appearance (Lawrence et al. 2005). By the same token, the higher abundance but lower frequency of *F. virosa* in the present study is apparently due to its low utility.

5.1.3 Species diversity and ethno- ecological importance of agricultural niches

Farm edges, which are usually resorted to border demarcation and fencing, stand second to none in ethno-ecological importance. This is in agreement with Kindt et al. (2006) in Western Kenya. Despite least in species richness and diversity next comes the homesteads while farms appeared ethno-ecologically less important as reservoir of wild fruiting species (Table 4.6). The latter is because farmers tend to be selective about species choice to ensure compatibility with food crops (Degrande et al. 2006) so that only a few species are tolerated. Generally, species choice of the different niches tends to relate to factors as relative importance and compatibility of the species and protection from unauthorized access. Trees perceived most important and compatible, as *Z.christi* and *C. africana*, are dominantly integrated in farms and homesteads. Conversely, those species perceived less important and or incompatible with annual crops like *F. virosa* are mainly retained on farm edges and on uncultivated plots.

By and large, as it stands today wild fruit bearing species are inserted in low stocking rates and only in limited niches and are exploited almost completely neglecting the fruit component. There are, however, several niches which they can suitably be integrated to serve both conservation and production services. Especially the underutilized homegardens have great potential to accommodate a good number of species that can provide both fruit and cash income and many other non-fruit services like windbreaks and hedges, while at the same time they play a conservation role. Literature also shows that wild foods are components of the complex multi-storey homegarden systems (Scoones et al. 1992). Homegardens are ideal niches as they are the only place which farmers feel secured of their land tenure and can easily be guarded against unauthorized access. Some species are typically suitable for growing in homesteads. For instance, *D. abyssinica* which has a much better flavor than *D. caffra* that occurs as a famous fence elsewhere in Ethiopia (Edwards 1992), can be domesticated as live fence in the homesteads especially in the barren Debark area where it occurs in relatively high numbers in the surrounding wilderness. Further potential for incorporation as live fence lies in *X. americana* (Edwards 1992), *Carissa* species, *Rubus* species and *R. abyssinica* (McLachlan 2002). Several other species can be inserted through the modalities of fence, shade, garden and roadside plants and in vegetation programs (Zemede and Mesfin 2001).

Furthermore, wild fruits can also be grown in schoolyards, parks, market places, around rural buildings like in the Farmer Training Centers (FTCs), riverbanks, city lanes, churchyards, mixed in woodlots and other common lands. Especially, integration of wild fruit species in the ever-expanding Eucalypt woodlots could be taken an opportunity to not only exploit their fruits but also combat some of the negative effects associated with Eucalypt monocrops. The SMNP and the several small parks established in *Woreda*s and *Kebele*s in commemoration of Ethiopian Millennium can also offer excellent opportunities for domestication.

Planted along riverbanks as groves, riverine species like *S.guineense* can improve water quality by reducing sedimentation loads. Besides, they could greatly be of assistance in soil and water conservation especially in the densely populated highlands such as the Debark area, by planting them on contour structures, inside and along gullies and several unsuitable areas for farming. In total, while some wild-harvested species may need sustainable harvest *in situ,* several others have the potential to be brought into human managed landscapes through agroforestry for sustainable utilization and conservation.

5.1.4 Factors hindering integration to and diversity of wild fruits in agricultural landscapes

Several technological, biological, socio-economic and cultural impediments have to be tackled before wild fruits are getting grip on farms. Consistent with Kindt et al. (2006), free availability in the natural environment is one of the major reasons for not growing wild fruits in man-managed landscapes. It is true that where life is characterized by urgent general scarcity of daily necessities, like in the study area, planting trees for future use may not appear a particularly relevant endeavor (FAO 1985; Akanafasi et al. 2005). Therefore, the free availability mindset does not warrant investment of meager resources into tree planting and has in fact greatly influenced domestication, in some cases to the extent of rebuffing freely supplied planting materials from local DARD Offices. This is well corroborated by the findings of Krause and Uibrig (2006) in central Ethiopia that deliberate tree growing is perceived as the third activity for income generation after agriculture and livestock rearing. In the study areas where farmers mainstay is agriculture, their leaning towards it than trees should not come a bolt from the blue, as forest foods generally play a supplementary role in the diet and rarely constitute staple foods (FAO 1995). This is in concurrence with Below (2004) and Place and Otsuka (2002). From the study it becomes also evident that literate household heads tend to retain wild fruit trees as opposed to illiterate ones (Table 4.7). This might be because literate heads can easily understand the benefits of trees in farms due to their schooling or as they read extension flyers or can easily perceive extension advices. Thus the low level of domestication of wild fruit species and trees in general might partly be explained by a low literacy level where nearly half of the sample households had not had schooling or dropped out before they had learned to read and write.

On the other hand, against the popular belief that people having extension contact would be agro-forestry adopters (Pattanayak et al. 2002; Thangataa and Alavalapati 2003), the present findings show otherwise, which awaits further investigation. This can perhaps be explained by the crop biased extension service that encourages farmers’ inclination to maximize crop production in monocrops by barring trees. This is consistent with what has been suggested by Scoones et al. (1992). Participation through groups and the support of a community network is expected to help adoption (Pattanayak et al. 2002). Concurrent with this, household heads that have responsibilities in the community tend to have trees in their farms. Their participation might perhaps have helped them to learn from their peers' experiences. The study also illustrates that people who possess larger plots tend to have trees on farm. Among physical factors, slope and altitude appeared to influence farm occurrence of wild fruit tree species in different directions (Table 4.7). Consistent with other studies (Bannister and Nair 2003; Degrande et al. 2006) plots located at steeper slopes have trees than those in lower slopes. This can be explained by the higher erosion rates on steeper slopes that might have forced people to accommodate trees to combat the effect. Conversely, it might be that steeper plots are no more suitable for crop farming.

Another problem emerged during discussions with farmers was ecological niche differences between the natural and agricultural environment. In this regard, some habitat specific fruit tree species can not easily be brought into various soil types and terrains where different types of crops have been adapted over time. For instance, forest species requiring ample shade and cooler temperatures and species common to riverbanks that need more moisture than garden conditions might not be suitable for garden transplantation (Johnson 2002). Another lamented factor for limiting farm integration of wild fruit plant species was their incompatibility with annual crops due to space competition, shading and some undesirable morphological characteristics. Nevertheless, this should not be discouraging as it can easily be tackled if appropriate tree management practices are adopted.

Domestication of wild fruits seems also largely constrained by the near to the ground prices. Of course, the incentive to plant and manage trees in farmlands is overridingly provided by development and expansion of markets (Leaky 1999). Looking at cultural aspects, overridingly negative connotations attached to wild fruits are at the roots of their disregard to a significant degree. So are unfounded beliefs and prejudices that disfavor the expansion and sustainable use of the wild fruits. According to Guinand and Dechassa (2000) strong traditions, beliefs and religious taboos still obstruct people's psychological and mental willingness to domesticate and cultivate wild food plants in Ethiopia. For instance, in the study areas, tamarinds are avoided to be grown in the homesteads for they are believed to shelter bad spirits that invite thunder. Such reputation of association of tamarind trees with malign spirits and taboos is also believed in parts of India (FAO 1985) and in Luo communities of Kenya (ICRAF 2002).

Another insight from the study was that within the limited species currently available in the agricultural settings, species richness and abundance of trees vary from field to field and site to site. Among several factors that have been hypothesized to bring about such variation altitude has a significant negative influence (Table 4.8). As one goes from lower towards the higher altitudes, both the level of domestication and the number of species and trees per farm progressively and then sharply dwindles. As discussed previously, since retaining of natural regenerants is a norm for bringing trees in farms, the poor natural vegetation backdrop of the higher altitudes does not offer farmers a wider chance to finding trees to be retained. On the other hand, the size of landholding appeared to have a positive relationship with farm integration as well as abundance of trees on farm. Plot size is related to economies of scale explanation that a farmer with more land is more able (Pattanayak et al. 2003). Hence, as size of land of the household increases there is a probability of retaining and maintaining a higher number of fruit trees on a farm since the large land size permit households accommodate both staple crops and trees. From the above discussion it is apparent that domestication of edible fruit bearing species in agricultural landscapes is constrained by a multitude of factors. This would undoubtedly culminate in over-exploitation and depletion of natural stocks and points towards the need for easing the constraints and encouraging domestication if they have to survive in appreciable quantities.

5.2 Cultural domain of, and local knowledge and species preferences for wild fruits

5.2.1 Cultural Domain and knowledge of informants

As judged by free-lists the wild fruits domain of the study area is rich. Besides, each locality is bestowed with a range of species some of which though pretty important in one locally hardly ever known or virtually inedible in another. Nevertheless, a few species as *F. sycomorous* and *C. africana* are well known by informants across all areas. Particularly, Adiaregay, Bermariam and Dibbahir sites appear to be very similar with respect to fruit species making up their domains (Figure 4.12). This familiarity of species over wide areas elucidates that apart from site specific knowledge there exists a common knowledge across a range of different cultural and geographic areas (Kebu and Fassil 2006).

In a free-list exercise, the differences in list length and content are measures of intra-cultural variation where individuals who know a lot about a subject expected to list more terms (Quinlan 2005). In view of this, the present study ratifies that knowledge of species is heterogeneous among informants. Ethnobiological knowledge and practice within any culture varies depending on factors as geographical origin and several socio-economic and cultural attributes (Gisella 2006; Setalaphruk and Price 2007). In the present case, people's familiarity of species appear to be highly dependent on age as youngsters are more knowledgeable than elders (Tables 4.9 & 4.10). This is consistent with other studies (e.g. Styger et al. 1999; Tigist et al. 2000). Here it is interesting to mention that especially informants in the teens are very knowledgeable. This might partly be due to differences in consumption preferences between adults and youngsters. Normally, adults keep away eating most species for various reasons as a result their lists might be limited to only those species they are accustomed to eat than what they know. It might also be that driven by food scarcity some species that were not known in earlier days have now become edible by the younger generation. This is corroborated by the findings of Tigist et al. (2006) in Dheeraa area of Arsi, Ethiopia who reports that children like to eat fruits of the recently introduced *Prosopis juliflora* while adults do not.

Besides, the degree of use and knowledge about a species is often associated with the morphology and phenology of plant species and familiarity with the forest terrain (Wong et al. 2002; Shresta and Dillon 2006; Pardo-de-Santayana et al. 2007). In the context of the present study, therefore, it is not surprising that children who have direct contact with the natural landscape in everyday life and have hands-on experience in gathering recollect more edible species. While their intimate associations with the landscape furnishes them a chance for ecological literacy and perpetuate knowledge of edible species, it also provides them a chance to continually experiment and add more species to the menu from time to time.

On the other hand, knowledge differences between informants of different sites could be explained by other broader factors. For instance, differences in access to and type of natural vegetation, which is dictated by the level of anthropogenic intervention and climate of the area could discriminate the level of informants' species familiarity. Accordingly, informants located far away from the forest and dominantly influenced by the town milieu, like Debir and Adiaregay, tend to be familiar with relatively fewer species while those close to remnant forests (at Bermariam and Dibbahir) mention quite a number of different species. This in agreement with Van Den Eynden et al. (2003). It may also very well be that in the highly populated highlands where intensive cultivation is the norm, biodiversity is considerably reduced and the possibility of acquaintance with wild fruits minimized. However, this alone cannot explain the difference since while Debir and Dibbahir sites are located adjacent to each other they differ in knowledge of informants which unquestionably goes to some cultural and socio-economic differences.

In sum, the present study confirmed the presence of still a wealth of genius on a variety of wild fruit plants on the part of the local community especially the youth. The preservation of such knowledge is resulted from the continued reliance of local communities on these resources (Kebu and Fasil 2006) while the existence of greater knowledge on the part of the younger generation is a good signal for the perpetuation of indigenous knowledge.

5.2.2 Species saliency and informant consensus

A salient species is one with high frequency of mention by informants, appearing early in their species listing (Martin 1995) and corresponding to a higher Smith's (S) saliency to reflect the familiarity level of the species in the community. Accordingly, *C.spinarum*, *C.africana, F.sycomorus* and *Z.christi* appear to be the most salient species across the study areas that translate into prototypical to wild fruits domain and more significant to the informants. Nevertheless, slight variations are apparent among sites with respect to the extent and types of salient species. Again, Adiaregay, Bermariam and Dibbahir showed a higher resemblance in the type of salient species. This can be explained by their similarity in climate that shaped the types of species occur which in turn resulted in a shared culture among people of these adjacent sites. In Kurar, however, being a more isolated site, a lack of information sharing and differences in culture may account for its peculiarity.

Saliency level of species did also slightly change by the scale of cultural domain analysis. This could be explained by the scope of distribution of the species that the wider the distribution the more familiar and significant a species will be to informants of several sites. The implication is that assessment of wild fruits cultural domain at a higher scale (aggregated data) than a lower is very likely to masquerade the knowledge, interests and preferences of the local community at respective sites. There appeared also a relation between species in free-lists in terms of how people think of them that gave the domain a structure. Generally, one can differentiate between more salient species, mentioned together by many and those less salient and mentioned by a few (Figures 4.15 & 4.16). The later species are rather less important as only a few individuals hold knowledge about them (Castaneda 2004). Besides, respondents of the same locality show a tendency to name similar species that occur very closely together. This concurs with Tigist et al. (2006), and apparently shows a shared culture among informants of the same sites.

Consensus analysis provides a framework and method of analyzing patterns of agreement among respondents from which the amount of knowledge can be inferred for each respondent (Borgati 1994), Table 4.11. Accordingly, except at Kurar informants have a higher consensus implying that they were drawn from a single culture in their own respective localities. Thus, the variations in their answers are unsystematic arising simply from variance in cultural centrality (Borgatti 1994 & 1997). On the other hand, a relatively lower pseudo-reliability at Kurar indicates that the consensus among the informants is low which might be attributed to the small sample size (Sinha 2003) rather than giving rise to the assumption of more than one culture. However, it is also apparent that the wider the scale of analysis the lower the numbers of species in the consensus model. This indicates cultural differences between informants of the different sites. Hence, as cautioned by Borgatti (1994) aggregating the data to obtain a majority view from across all respondents of different sites that are of distinct sub-culture would be a futile exercise.

5.2.3 Species preference

The present study confirms that each locality has its own species preferences. Even within a given locality, informants' species preferences appear to vary slightly by age groups (children or adults), sampling unit (individual or group) and scale of analysis (district or site). Adults perceive the value of wild fruit species primarily in terms of their non-fruit services while children rate them based primarily upon their fruit values. This is consistent with Tigist et al. (2006). This would have grave implications that, since in most cases adults are the decision makers of the family, wild fruit species will most likely be exploited for non-fruit utilities than fruits.

Figure 5.2: Fruiting branches of *T.indica* near the Blue Nile River at Kurar

Even in close-by sites slight variations were observed, if not on the type, in the order of most preferred species. This is not surprising in view of the wide array of ecological niches and practices at short distances which can bring about slight cultural differences. For instance, while Bermariam and Adiaregay are adjacent to each other and in the same climate, because of influences from neighboring Tigrayan people language and culture, species choice of Adiaregay informants' and even vernaculars appear to slightly vary from

Bermariam. Species ranking was also suggested to vary among different areas or communities because of species distribution, indigenous knowledge and economic pursuits of the community (Pauline and Linus 2004). In the present case, the presence of a marked variation in species distributions especially between Debir and the other four sites has without doubt influenced species preferences.

All in all, *Z. spina-christi, R. abyssinica, Carissa* species*, D. mespeliformis, S.guineense, T.indica, M. kummel, D. abyssinica* and *X.americana* are among the most appreciated species across the study areas (Figure 4.17). Interestingly, except *D. abyssinica*, these species are in commerce in their respective localities which might be the major criterion considered during preference ratings. It is also interesting to note that the most preferred species by and large match with the most salient species identified in the cultural domains of respective localities.

Figure 5.3: Fruiting branches of *Z. spina-christi* at Bermariam *Kebele*, Adiarkay

Hence, from the perspectives of the local preferences and other criteria such as multiuse value and marketability these species could be given priority for promotion to wider consumption and domestication. Of which, *M. kummel* fits in the national priority list (Demel and Abeje 2004) while *Ziziphus* and *T. indica* are within IPGRI`s priority underutilized fruits species in Eastern and Southern Africa (Williams and Haq 2002). Hence, there is a good prospect and opportunity for the domestication of these species making use of knowledge from country and regional collaborative research.

5.3 Wild fruits regeneration, tree management and fruiting phenology

For most species, seeds achieve acceptable level of germination without any or partial pre-treatment. However, animals, both domesticated and wild species, also play a great role in the regeneration of some hard-seeded fruit species. For instance, *Z.christi* and *C. africana* are given a pre-treatment status by goats while wild animals are crucial for the regeneration of *D.mespiliformis* and *T. indica*. The role of birds and other wild animals in seed regeneration has also been reported by Demel (2005) in Ethiopia and Styger et al. (2004) in Madagascar. Nevertheless, sometimes animals could play a negative role by devouring seeds along with the fruits. Other species as *X. americana* have characteristically very poor regeneration capacity which in the latter can partly be attributed to its recalcitrant seed (Girma 1999). Hence, if the seeds miss the opportunity to germinate soon in the same rainy season fruits are produced (which is habitually low and erratic in the study areas), they will have a low chance to pass through the long dry spell and to germinate by the next year's rain. In *D.mespiliformis*, *T. indica* and *X. americana* regeneration is low due to their slow growth habit. That these species have adapted to the dry lands slow growth might of course be a mechanism for drought tolerance as plants usually exhibit a slow rate of shoot growth, as a common evolutionary response to habitats where the length of dry season is long (Appiah 2003). It was also noted that the informants' knowledge of wild fruits regeneration mechanisms is generally low. This is consistent with farmers in Southern Ethiopia (Guinand and Dechassa 2000) and is reflected by their noviceness to other than seed means of regeneration and unaccounted regeneration mechanism for some species. The latter might arise either from the tiny nature of seeds (like in *Ficus* spp.) or from the long dormancy of the seeds as *Rubus* spp. (MacLachlan 2002) that people are not able to discern them.

As a result, domestication is initiated for the major part by retaining natural regenerants and transplanting wildlings that would confer inferior yield and quality. Besides, though it could be seen advantageous as it offers free access to farmers, transplanting of wildlings could contribute more to real disappearance than to species preservation as it removes the entire plant from its natural habitat (Johnson 2002). Generally, support and encouragement of farmers for artificial regeneration of wild fruits by governmental and NGOs appears very low.

Although there exist reportedly two NGOs, SIM and CPAR, for raising and distributing seedlings of some indigenous fruit species to farmers in northern Ethiopia (Demel and Abeje 2004), it seems that the study areas do not have access to. Overall, the study suggests the urgent need for introducing vegetative propagation, as noted by Akinnifesi et al. (2005), to rapidly multiply, test, select from and use the large genetic diversity.

Fruit bearing trees retained or planted in farms are in the majority of cases grown unattended especially with respect to fruit production. This is in conformity with reports in southern Ethiopia (Guinand and Dechassa 2000), Madagascar (Styger et al. 1999), Uganda (Okullo 2005) and Kenya (Pauline and Linus 2004). More often than not, fruit trees are managed towards encouraging full or at least greater light transmission to the understorey. For this reason they are kept shade-free by all possible means for the accompanying annual crops. Even worse is the fact that since these management practices are carried out regularly almost every year, plants hardly get a chance of attaining fruit bearing stages. Consequently, fruit production is improbable in farms unless the fields are left fallow, which is a narrowing possibility in the present days. Should these species be an important agroforestry trees both providing food and serving other multi-functions, however, effective management and establishment regimes that optimize production with a range of annual crops need to be established.

5.4 Ethnobotany of wild fruits

5.4.1 Fruit seasonal availability and consumption

The season of fruit harvesting varies from place to place, species to species and even from tree to tree due perhaps to climatic and intra-specific variations, respectively. In Ethiopia, seasonal food shortage is a common phenomenon in every part of the country usually from July to September (Getachew 2001), by which time storage bins gone empty and the new crop is yet unready. Fortunately, in the study areas a good number of wild fruit species are available for use by these times (Figure 4.18). More interestingly, however, quite a large number of species bring forth their fruits from the month of January onwards which largely coincides with the cyclic long frugal Lent fasting period that lasts 55 days. During this time the majority of Orthodox Christians have to survive with only one or two meals a day that are completely devoid of animal products. In addition, the annual Islamic holiday, Ramadan, most often falls during these times and is again marked by a whole day fasting. The collection and use of wild fruits at these times will thus be a timely and chief essential nutrient provider and a valuable adjunct to the cereal dominated food. This points out that the wild fruits in the study areas have a great potential not only to bridge a hunger gap but also to supply essential nutrients at the time of need.

Overall, it can be surmised that the year-round availability of a series of different species within and across the study areas provides opportunities for year round food and nutrition supplement and development of remunerative enterprises. As such, this can motivate local people to conserve wild resources and encourage domestication. Moreover, seasonal variation of fruits between localities could open a room for trading across areas as is the case with *T. indica* fruits that thrive between Kenya and Tanzania, due to fruiting season differences in the two countries (Pauline and Linus 2004).

Oddly enough, however, while the study areas are sustaining tragic food insecurity the current level of fruit consumption is very low compared to other countries like South Africa where wild fruit consumption has been reported as high as 104 kg per household per year (Shackleton and Shackleton 2004). In most cases, wild fruits tend to be sporadically collected and used on a casual encounter than on a regular basis though this varies with the type of species. Several factors such as advent of cultivation and preference for modern agricultural crops, level of indigenous knowledge and economic pursuit of people are widely referred to as contributing to the low level of utilization of wild plants including wild fruits elsewhere (Zemede and Mesfin 2001; Pauline and Linus 2004). While all these might as well hold true in the study areas, people's dietary habit, which are highly dependent on cereal-based food, chiefly Tef (*Eragrostis abyssinica*), remain a major part of the explanation.

More importantly, individual decisions regarding food acquisition and consumption are guided by local cultural perceptions, attitudes and beliefs and are seldom independently made or value-free (FAO 1995). In this regard, local taboos seem to awfully discourage the consumption of wild edible fruits and plants in general. Wild fruit gleaning is interpreted as "*being famished*" and their consumption connotes indignity and social stigma. This is of course not surprising in a community that is even a novice and reluctant to most of the commercially well-known fruits and vegetables. Thus, breaching the unholy wall between wild fruits consumption and the discredit by mainstreaming at grassroots level may need to be a central pillar for wild fruits exploitation. Furthermore, external famine interventions were suggested to lead to dependency on non-local resources and disincentive to raise local productivity (Webb and Braun 1994). To this end, neglect and insignificant consumption of wild fruits especially in Debark and Adiarkay areas could partly be attributed to access to a relief food. Moreover, population decline in several fruit species seems to result from increasing difficulty of finding in the wild

In addition, the present findings disclose that fruit gleaning and consumption is to a great extent the children's domain, where some fruits are all the more considered to belong to the children's category because grown-ups entirely avoid their consumption. This is in agreement with previous reports in several parts of Ethiopia (Edwards 1992; Bell 1995; Guinand and Dechassa 2000; Getachew 2001; Getachew et al. 2005; Tigist et al. 2000). Fruit consumption tends to decrease with age that they are largely consumed at childhood but most of them are gradually given up as the people grow up. This is certainly because grown-ups get more exposed to the culture of the society that regards wild fruits a low status and their consumption a source of shame. Similar reports in Eastern Africa indicate that fruit consumption decreases from young to adult people but in this case increases again with old people (Kweka et al. 2004).

Gender differences were not found to affect the consumption of wild fruits. Nevertheless, pregnant women were found to be fond of wild fruits. Children, as well as pregnant and lactating women, are most vulnerable to nutrient deficiencies (Scoones et al. 1992) and there is evidence that lactating women consume greater quantities of bush foods to acquire additional vitamins (FAO 1995). Therefore, the increased consumption of wild fruits by children and pregnant women in the present study can be taken as a positive development in a sense that these groups, who are particularly prone to malnutrition, could have access to essential supplies of fats, proteins, vitamins and minerals (Bell 1995).

Many wild species grown or wild-harvested provide vitamins, flavorings and the like of nutritional, gastronomic and social importance obtained from secondary products of metabolism such as alkaloids, essential oils and phenolics (FAO 1999) which the normal agricultural produce does not adequately provide (Demel and Abeje 2004). The present study confirmed that some species as *D. mespiliformis*, *M. kummel*, *T. indica* and *Z. spina-christi* fruits are laden with important nutrients (Table 4.13) and have great potential to serve an important source of vital nutrients especially to the growing children who are prone to malnutrition (Pauline and Linus 2004). This implies that if the wild fruits were not available, the variety and quality of the diet especially for children would have been reduced merely to carbohydrates. Nutrition information was lacking for wild fruit species in Ethiopia (Demel and Abeje 2004) and this remained so, perhaps up until the present study. This inadequacy of their nutrition information and subsequent misunderstanding of their potential has indeed resulted in neglect of these species (McBurney et al. 2004) while it limits educational efforts to improve diets (Grivetti and Ogle 2000).

5.4.2 Mode of utilization, nutritional value and role at times of adversity

Concurrent with several reports elsewhere (Murray et al. 2005; Van den Eynden 2003; Musinguzi et al. 2006; Redzic 2006), most of the wild fruits are eaten fresh and raw or sometimes in the form of potion. Of course, for some fruits some form of home processing such as boiling, roasting and fermentation are practiced. They are processed into either a form of refreshing juice or brewed into local beers with or without the addition of a fermenting agent, *R. prinoides*, or are added as flavorings to local drinks (Table 4.12). The use of fruits in the form of juice or beer was similarly reported for *S. guineense* and *X. americana* (Kebu and Fassil 2006), *T. indica* (Demel and Abeje 2004; Pauline and Linus 2004) and *F.sycomorus* (Tabuti 2007).

There is, however, a significant potential for the improvement of the contribution of wild fruits through processing, from which a number of products could be produced commercially. For instance, there is a potential for the processing *C.edulis, D. abyssinica, Rubus* spp., *O. ficus-indica, R. abyssinica* and *S. guineense* into jams, marmalades and jellies (Edwards 1992; Zemede and Mesfin 2001) while *Carissa* species can also made into vinegar by fermentation (Mac Lachlan 2002). Fruits of *M. kummel* have prospects for jams and jellies (Demel and Abeje 2004). *T. indica* can be processed into juice, confectioneries, soup mixes, non-alcoholic, composite seasoning and oil (Williams 1997). While products of the latter species are highly developed and widely used in Asia, so far little is used in Africa (Leaky 1999) and almost none in Ethiopia. Generally, processing of fruits could enhance the improved and efficient utilization of the products by reducing wastage while it could also promote the conservation of the species for the sustainable supply of raw materials.

Obviously, when food security is threatened, farmers rely on a variety of coping mechanisms to overcome the crisis. Various studies (Abbink 1993; FAO 1999; Guinand and Dechassa 2000; Demel and Abeje 2004; Kebu and Fasil 2006) document that some wild fruit species are consumed only during times of famine. Strangely, however, although the study areas are among those often hit by periodic drought and food insecurity, the study did not encounter wild edibles of the only famine category on the part of wild fruits. It might be that in the face of recently mounting food insecurity in the area, wild fruits have become a commonplace surviving strategy and are consumed during normal and famine times alike. An alternative explanation might be that people are resorting to other life forms like roots and wild animals to coping with stress. In famine periods, roots, tubers, rhizomes and nuts are most sought after, as they are characteristically energy rich (Arnold 1995). This also concurs with Guinand and Ugas (1999) and Zemede and Mesfin (2001) who report that during critical food shortages as in famine leafy wild plants are used than wild fruits. Nevertheless, the intensity of fruit use appears to swell enormously during famine times, especially on the part of poorer families, which is in agreement with reports by Guinand and Lemessa (2000) in the Konso area of Southern Ethiopia.

5.4.3 Disagreeable effects of wild fruits consumption

A plant customarily recognized as innocuous may prove harmful or toxic depending on the susceptibility of the individual, the part used, the growth stage, the way it is prepared etc., (Dawit et al. 2001). In the study areas, a few species were unanimously complained about and asserted to incite harmful reactions, mainly stomach complaints in various forms, thus dissuading people and affecting their popular appreciation. Sickness effects are pronounced especially when fruits are eaten unripe or taken in excess amount or in a fasted stomach (Table 4.12). Harmful reactions and in extreme cases death were also reported in other studies in the country (Guinand and Ugas 1999; Getachew et al. 2005; Kebu and Fasil 2006). The negative effects of the raw use of fruits are undoubtedly accounted for by toxic phyto-chemical constituents of fruits. Fortunately, however, people practice a variety of local methods to mitigating the negative effects.

Sometimes wild fruits do not have mercy upon animals either, a very grave case of which being goats' and camels' consumption of seeds of *L. senegalensis* that causes their instantaneous death, as was reported in the Gamo area of southern Ethiopia (Kebu and Fasil 2006). Sadly enough, the exocarp of the *L. senegalensis* fruit is consumed by humans especially children, which could accidentally poison them. Seeds of *S. spinosa* and *X. americana* are similarly reported to have toxicity (Amare 1976). Generally, though the condition often goes undetected in the absence of acute symptoms, a prolonged consumption of food containing natural toxins may bring about chronic toxicity exhibited by reduced growth, digestive disturbance or aggravation of malnutrition while it can also markedly affect the person’s productivity (FAO 1995).

5.4.4 Fruit transaction and income generation

The study uncovered that marketing of some ten wild fruit species is underway over Adiarkay, Debark and Dejen markets. However, the type and number of fruit species marketed appear to vary by location, year and season. While some historically consumed species like *M. kummel* are sold across locations others like *D. mespiliformis* are sold only in specific market places and do not feature elsewhere (Table 4.16). The implication is that the later species will only have local importance and their commercialization potential over wider markets would thus be less promising.

Figure 5.4: Wild and domesticated fruits on sale in the same market stand: *M.kummel*, Lime and Citron

Marketed species are in almost all cases collected from the wild and are mostly article of commerce at the nearby rural town markets within the collection points and a few fruits are transported to distant markets within and outside the region like to the neighboring Tigray region markets (*Z.spina-christi*) and to the metropolis (tamarind). In a few cases they are even shipped to neighboring countries like the Sudan, as was also previously reported by Demel and Abeje (2004). Of course, if the market qualities are maintained, apart from its potential at the cottage industry level, tamarind has a great potential for export (Edwards 1992). Surprisingly enough, however, while the country is one of those with largest tamarind tree population in Africa reports show that from 2000-2002, 43.5 and 7.0 metric tones of dry and fresh Tamarind in that order were imported from India (El-Siddig 2006).

In the study areas, especially at Debark and Adiarkay, there is also unexploited potential to targeting wild fruits to tourists. These market opportunities can generate additional income to poor farmers in such less-favored environments where these crops have comparative advantages over major staples or commercial crops (IPGRI 2002). Besides, there is also an opportunity to consider some fruits like *Z.christi* for marketing for livestock feed.

Marketing chains are uncomplicated in the way that in the majority of cases the same people harvest the fruits used for sale. For the most part, wild fruit marketing is done by women rather than men. This is in agreement with reports from other places (Demel and Abeje 2004; Styger et al. 2004; Shackleton and Shackleton 2004 and Packham 1993). Likewise, retailers as well as customers are for the most part women and children (Figures 4.20 & 4.21). This concurs with Zemede and Mesfin (2001) and shows that fruit trading is more attractive to women than men. It might also mean that in order to maintain their supremacy men care for their celebrity and dignity and shun wild fruits deal. Of course, this is also historical that wild plant gathering for food was traditionally a female responsibility in most hunter-gatherer societal groups.

Nevertheless, seasonal gluts are very common and fruits generally achieve very low prices especially at peak fruiting season, are species dependent and vary by location and mode of sale whether retailed or whole sold (Table 4.18). Generally, low fruit prices are mainly attributed to seasonal availability of fruits and random entrance of many casual people saturating the markets. For instance, the majority of wild fruit vendors are people with temporary stalls (Table 4.17). Poor marketing can result in major variations in price, a factor of from one to ten between peak and off-peak months (FAO 1995). Low prices due to seasonality can also be seen in terms of inter-year differences. For instance, in drought periods wild foods become very important and the prices might increase significantly, compared to normal periods (Scoones et al. 1992). Therefore, the present study undertaken in a single and relatively normal year it might have somehow underestimated fruit prices. In addition, most fruits are usually sold simply on judgment basis which could again substantially undermine fruit prices.

Besides, because of absence of preservation technologies and perhaps urgent cash needs, most fruits are disposed to the market right after harvest. This again influences the fruit prices. The shelf-life and or storability of most wild fruits are generally short on account of their high water content complemented with inappropriate handling. In fact, their longevity can be enhanced through preservation by fermenting and drying which are accessible to the poor as most of these small-scale processing activities require little in the way of capital or skills to enter (Arnold 1995).

What follows is that though wild fruits have been widely reported to generate substantial cash income and thereby contribute to the welfare and livelihood of rural people (Bell 1995; Sundrya and Sundrya 2003), the income earned in the study areas appeared generally very low. This is consistent with Musinguzi (2006) and Sundrya and Sundrya (2003). Even then, the poor segment of the community makes part of a living out of their trading. Therefore, the study emphatically stresses the necessity to promote value addition techniques for better economic profit of the local community so that their venture will be crowned with success. What is more, there is a need for wild fruits domestication for which farmers may need to be supplied with superior stocks. This would help to combat seasonality of production through variations in maturity or fruiting several times a year and avoid the boom and bust economy (Leaky and Simon 1997; Penn 2006).

5.4.5 Non-fruit use diversity

Apart from direct food value, wild fruit tree species were reported to serve various utilitarian functions pertaining to social, economic and ecological services (Edwards 1992; Zemede and Mesfin 2001; Ogle et al. 2003, etc.). It is well true in the study areas that every conceivably wild fruit bearing species is valuable in several other ways and, except for a few species, food value has a rather subordinate role. Most of these species offer several direct use values. For instance, some species have a nutraceutical value, which means that when they are eaten for their nutrition role, circuitously they improve health conditions, according to FAO (1995), thus contributing to the effective biological utilization of food by the individual. This might be due to their contribution of small quantities of trace minerals and vitamins (Ogle et al. 2003). Others like *M. africana* are directly used in folk medicine and improve health. *M. africana* and *T. indica* were also previously reported in the country (Zemede and Mesfin 2001; Demel and Abeje 2004).

Wild fruit tree species are also widely used for house construction, furniture, farm implement making, hand tools, etc. For instance, one of the most farm integrated species, *C. africana*, is highly threatened in recent days, due to a very high demand for its wood by sawmills and local rural handcraft men alike. This is in agreement with Kebu and Fasil's (2006) report from southern Ethiopia. Their value as animal feed is particularly important in the event of awful scarcity like in recent times. These parallel functions as livestock feeds make animal products more accessible to poor households and help improve the quality of their diets (Ogel et al. 2003). Another interesting role of wild fruit species that was seen negatively by informants is supporting and sustaining lives of wild animals and avian community that would have disappeared or become problematic on domesticated crops otherwise. This helps maintaining the wild animal diversity which would in turn serve in a beneficial way by facilitating regeneration and rescuing wild fruit species diversity. Kannan and James (1999) have similarly reported a keystone role *Ficus* species were used to play in the maintenance of the avian frugivore community in southern India. Besides, given the existing free animal grazing system, fencing is an important instrument that helps making crop harvest possible by warding off animal foes, while at the same time it saves labor expenses for guarding. Hence, the use of wild fruit species for live or dead fencing also functions as the foundation for the livelihood of many people. This is also true in other parts of Ethiopia (Zemede and Ayele 1995).

Mention should also be made of the value of wild fruit species in indirect use values like environmental servicing. As such, in the face of the swiftly declining soil fertility, some edible fruit bearing wild plants as *C. africana, Carissa* spp. and *R.abyssinica* are increasingly getting recognition by farmers for their soil fertility benefit. A local saying "*Ye Agam Bet Dagusa*", which is to mean a copious crop of finger millet on Carissa clearings, evidently substantiates this. Furthermore, some remarks on non-use values like cultural and spiritual value of fruit species should be made. Some wild fruit species are widely used for condolence expression, crop yield prediction, are components in the verses of songs, sayings, blessings, etc. For instance, wild fruits are mentioned in Amharic songs; "*Yeshimbiraw Tirtir Yezafochu Fire Yetim Yetim Zore Tiz Alegn Hagere*" to express nostalgia about one's birth place that was used to grows fruits; "*Yehagere Lij Nat Damay Yematitegeb Enkoy*" and "*Ye Abay Dar Enkoy Timechalesh Woy*" both used to express feelings of affection to a lady seen paralleled to the endeared Ximenia fruit.

In total, fuel wood, construction and fencing are the champions among the use categories, contributed mainly by *Z.christi, C.africana* and *T. indica* (Figure 4.19). These multiple uses attest to the on-going importance of these resources to local communities, for subsistence and as part of their cultural heritage (Shrestha and Dhillion 2006) and can lead to better chances for their conservation (Etkin 2002). They also offer an important, low-cost alternative to the cash economy, which may be prohibitive to the poor (Bell 1995), who are overwhelmingly cash-strapped. By contrast, wild fruit bearing species are under high pressure for their non-fruit services in that harvesting can pose them a threat (Shrestha and Dhillion 2003). This underlines the need for providing people alternative to non-fruit services required from wild fruit bearing trees. Overall, if more attention had been given for fruit uses too, there would also have been immense improvement in the basic nutrition and income of farm families (Edwards 1992). Offsetting such biased development path entails keeping a striking balance and judicious blend between non-fruit and fruit uses for which prime attention may need to be given to creating people markets for their fruits.

5.5 Fruits in homegardens: garden characteristics and agroforestry

components

5.5.1 Garden profile

The production of fruits in gardens appeared to have a recent history in the study areas that close to half gardens (45.7%) are only a decade old (Figure 4.24). This perfectly coincides with the time when the government of Amhara region embarked on an aggressive agricultural extension program of a green revolution archetype. The implementation of this program must have hooked up several farmers to improved technologies and raised their awareness significantly so that they might have been encouraged to enter into fruit crops production. In spite of this, however, there is a contrasting development of homegardens both within and between sites which can be accounted for differences in agro-climatic and socio-cultural factors (Zemede and Ayele 1995). Specifically, access to irrigation water and experience in other perennial crops growing seem outstanding factors. For instance, at Wogelsa site where irrigation dams were absent or dysfunctional, so is the history of gardening and fruit production in its infancy. On the other hand, at Zeghe the coffee cultivation has a long-standing tradition, and so has the history of gardening and fruit production (Figure 4.22).

The majority of gardens are located at the backyards immediately adjacent to the houses clearly demarcated from the outlying farms and more or less taking a rectangular outline (Table 4.19). Much of this is consistent with previous reports in Ethiopian homegardens (Zemede and Zerihun 1997; Zemede 2001). Their closeness to residences can be related to high security of the homestead land, easy scrutiny from unauthorized access, guarding against free roaming domestic and wild animals, easy access for monitoring cultural operations and maturity as well as providing house protection from wind. Nevertheless, there are also cases where gardens are completely disjoined and placed far away from residences which, according Vogl et al. (2004), could also be identified as rural gardens. Such distant gardens are more frequent at Andassa which is mainly because of the unavailability or unsuitability of homestead land or lack of water source. Generally, the distance of gardens relative to a house could have important implications on their management and biodiversity maintenance.

With reference to garden orientation, their placement more at the backyards than other locations might partly be explained by the need for open space in the front for sight seeing and various cultural and social functions. It might also be that backyards are perceived fertile sites as the household and kitchen wastes and manure are damped into. Moreover, gardens are often places where people call off nature and where night soils are deposited. Indeed, the relative location of neighboring houses, highways, waterways, etc. can have an additional bearing on the orientation of homestead plots. On the other hand, consistent with reports from other countries (Leiva et al. 2002; Albuquerque et al. 2005) the dominance of rectangular shaped gardens might have resulted from the plot shape households received initially for house construction. In this regard, the villagization programs that took place about two decades ago and the standard plot sizes (40 X 50 meters) that are currently allotted to a new family establishing households could have contributed much to take their present shape. The relevance of garden shape can be seen in terms of fitness to fruit production in a contemporary line like row planting and intercropping.

One of the close relationship between house, garden and family is the role the homegardens play in terms of security which is achieved through fencing in order to keep children and livestock in and others out, thus also protecting genetic diversity (Engels 2002). In the study areas, most gardens are fenced either by live or dead plants or by stone, live perimeter fencing being the dominant type. This is, indeed, a commendable practice as the live fencing can reduce costs while plants used in fencing can provide additional products for household use or sale (Marsh 1998) and provide improved growing conditions for plants (Minwuyelet 2004).

Figure 5.5: A homegarden at Wangedam, Bure: peach, banana and avocado in the front row

5.5.2 Homegarden land allocation

The average homegarden land holding per household (0.44 hectare) of the study households is fairly comparable to what has been reported for tropical homegardens, 0.50 ha (Fernandes and Nair 1986) and Ethiopian gardens, 40-500m^2 (Zemede 2001) as well as other countries (Wezel and Bender 2003; Kehlenbeck and Maass 2004; Das and Das 2005; etc.). Yet, there are great variations in their sizes among households that can partly be explained by the initial landholding status. Having been inherited from generation to generation through repeated sub-divisions by kinship and re-distributed in 1980's on a family size basis, the size of homegarden land remains variable among households. Remarkably, however, the majority of gardeners appear to be land owners who again have emanated from the former kinship inheritance landholding system. Of course, this kinship inheritance landholding system that assume a sense of ownership resulted in a higher degree of permanence and stability of the homegarden system (Zemede and Zerihun 1997) and would thus encourage growers to put in more effort to maintain the gardens without fear of uncertain tenure (Bennett-Lartey et al 2002).

Because of a higher precedence to field crops, however, area allotted to homegardening is a mere fraction of the total landholding and it varies from site to site. Since arable farms are entirely lacking, Zeghe recorded the largest homestead plot and thus the highest homegarden plot allocation (97.5%), Table 4.20. On the other hand, Wangedam has the smallest average homestead plot size (0.25 ha), so here most households (60%) have to depend on renting additional land. The study further disclosed that the total homestead land is not entirely allocated for fruit or horticultural crops production. More appalling is that not all households are engaged in fruit production which a substantial harvest gain could have been recorded otherwise. One can appreciate the fruit production potential of gardens by looking at the estimations for Bahir Dar Zuria *Woreda*, as an example. Assuming an average homestead land size of 0.5 hectare per household of the 31,973 households of the *Woreda* there would be 15, 986 hectare of homestead land. If a quarter of this land was allocated for fruits, nearly 4000 hectares of land could be put under fruit production. On a tree number basis, at a spacing of 64, 49, 36 and 2.25m^2 it can accommodate 625,000 avocado trees or 816,326 mangoes or 1,111,111 oranges or 17,777,777 bananas or papayas each. In sum, there is a great deal of homestead land that yet awaits to be put under fruit production.

From the study, it is also evident that households with small farms allocate a large share of their land for homegardening compared to those with medium and large size farms. For reason of economies of scale, households with large farm sizes overridingly concentrate on annual crops like maize that can satisfy their demand in the absence of fruits. However, the total land allocated for homestead use is still proportionately smaller for small gardens. This is consistent with Ahmed and Rhaman (2004) who report increased homestead size with an increase in farm size.

Overall, the low garden land allocation is explained by the high land pressure where arable cropping cannot fully provide households with enough calories (Hoogerbrugge and Fresco 1993). Conversely, the home gardens seldom meet the entire basic staple food needs of the family in any given area. Rather, they are complementary to other fields. Therefore, homegardens are a component of the larger farming system of the household (Marsh 1998; Kumar and Nair 2004). This is instructive that the promotion of homegardens as fruit or vegetable gardens alone is likely to be unsuccessful for subsistence farmers.

5.5.3 Biodiversity in homegardens

The importance of gardens as a system is based on the complex interactions it supports over time and which contribute to the sustainability of the system's production (Leiva et al. 2002). In the study areas, the homestead plots are chiefly managed in an agroforestry approach maintaining polycultural production with the objective of supplying households with supplementary staple and non-staple foods as well as cash and other services. The range of crops is extensive that trees, annual and perennial crops and animals are inextricably assembled temporally and or spatially except at Zeghe where the animal and annual crop components are very inconspicuous (Appendix 2). Nevertheless, crop mixes, extent and intensity vary among gardens within and between sites depending on individual household strategies, agro-ecological, socio-economic and cultural differences.

Apart from fruit trees, the tree component houses several multipurpose trees and shrubs including cash crops and indigenous fruit bearing species. Too often these species are maintained for various known and perceived benefits. Coffee, hop and chat appeared dominant cash generating species with a significant representation of the indigenous flora. This substantiates the suggestion that the homegardens may contribute to the conservation of native species (Albuquerque et al. 2005). This tree-based land use system can also help sequester carbon and contribute to climate change mitigation (Roshetko and Lasco 2008).

Like any tropical homegarden where food production was reported a basic function (Kumar and Nair 2004), gardens of the study area produce a variety of food crops maize being the most dominant as is the case with several parts of the country (Zemede and Ayele 1995). However, driven by the advent of synthetic fertilizers, improved varieties and cultural management practices as well as its good market prices, once an obligate crop of homegardens, maize is now becoming a field crop. This will undoubtedly leave a space for fruit production in homegardens provided that the latter could be remuneratively pursued. Besides, homegardening is regarded especially important in overcoming seasonal availability of foods and promoting household self-sufficiency (Talukder et al. 2001). In the study areas most homegardens house several hunger reliever crops, especially rape leaves (*gomen*), potatoes and pumpkins that mature very early when the harvest of the previous crops has run low and most other newly planted field crops are still in the field. This is why the most famous adage that goes "*Gomen Bawetaw Nebs Entat Alech Gebs*" (roughly translated as after the soul has been rescued by rape seed leaves, the late coming barley claimed the credit) widely heard among Ethiopians. Besides, homegardens house spice, aromatic and medicinal species that never feature in the surrounding fields. From a plant genetic resources perspective, it is obvious that the homegardens are important location for the cultivation of so-called neglected and underutilized species (Engels 2002). Hence, the present study re-enforces the notion that homegardens are repositories of rare species.

Figure 5.6: A homegarden at Andassa: mango and few papaya trees are dispersed over chat field; sugarcane at the back and guava as live fence to the right and far back

In addition, homegardens composed of animals which, apart from providing products and services, contribute to the maintenance of soil fertility and sustainability of the homegarden production system. Unlike several other countries like Bangladesh (Alam and Masum 2005), however, despite the great potential to incorporate fish species especially in the Lake Tana shore gardens (at Zeghe and Robit) this remains completely unseen. Fish ponds could obtain a dual role as a site for fish farming and as a source of water while fish could be fed on the chicken waste.

On the other hand, most of the homegardens reveal cyclical changes in biodiversity ranges season to season and year to year. Especially the diversity of annual crops and to a certain extent the animal component are very dynamic which is highly dependent on season, water and perhaps market availability. Dynamism with respect to the presence and developmental stages of perennial species and seasonal shifts in the kind, positions and amount of the herbaceous annual crop species had also previously been reported in Ethiopian homegardens (Zemede 2001), in Philippines (Boncodin et al. 2000) and Chibchan Amerindians of Costa Rica (Zaldivar et al. 2002). Whereas, the tree component including fruit trees shows more or less permanency and if there are changes at all, they emanate mainly from new plantings and removal through aging and death of trees. On the whole, the diversity of the system declines during dry seasons and increases during the rainy season. This is in agreement with reports of Zemede and Zerihun (1997) in southern Ethiopia. Such a partial or seasonal absence of components of the system indicates what is sometimes thought of by economists as a porous system (Huxley 1999).

In general, in the above scenario because of the management of a wide diversity of wild and cultivated plant species with different uses and the integration of animals to secure a full array of benefits the homestead production system appears to be sustainable. Besides, apart from maximizing the households benefit the presence of many multipurpose species in homegardens would help reduce the pressure on the surrounding dwindling forests and conserve species that would disappear otherwise.

5.5.4 Garden stratification

The vertical structure of the homegardens studied conforms well to other reports on tropical homegardens. Generally, where the agroforestry components are grown in a multilayered arrangement, albeit with only low visibility four different strata are recognized, in which most adult fruits trees dominantly occupy the third layer. This figure is comparable to reports on other countries homegardens (De Clerck and Negreros-Castillo 2000; Bennett-Lartey et al. 2001; Leiva et al. 2002; Wezel and Bender 2003; Das & Das 2005). This arrangement and vertical structuring of plants contributes substantially to the sustainability of the homegarden production system (Kehlenbeck and Maass 2004) in various ways. Firstly, the presence of different layers creates a gradient of light and relative humidity that result in different niches which can be exploited by different species and life forms (Ceccolini 2002). The multilayer plant cover intercepts rainfall efficiently and water retention in the aerial parts of the plants is improved. As a result, the impact of raindrops on the soil is reduced and soil erosion prevented. Moreover, due to litter fall, the organic matter increases and soil nutrients and moisture content are improved. Besides, a relatively constant moisture and temperature level at ground level is maintained, which reduces water stress in periods of low rainfall and maintains production through weather pattern fluctuations.

Figure 5.7: Horizontal stratification of crops at a Robit homegarden. Outwards from the house: papayas and other trees, maize, and millet in the outlying fields.

In most of the cases, agroforestry components are also arranged horizontally in differentiated zones relative to a house. There appear three different zones, the extent of which varies, depending on locality. Fruit trees are housed in the second zone next to spices and ornamentals along with other useful trees and shrubs as coffee, hop and chat. This is in agreement with Zemede (2001). Also, consistent with other reports elsewhere (e.g. Méndez et al. 2001; Belachew et al. 2003), spices, fragrant and ornamentals are close by the house. These zones often serve several purposes including water and humidity regulation. Generally, the location, size, plant species composition and their local uses included in different zones, mirror the farmer's management priorities and socio-economic needs (De Clerck and Negreros-Castillo 2000; Mendez et al. 2001) and are in deed a product of culturally and socially defined differences in gender roles and expectations (Lok 2001).

5.6 Fruit species assessment of homegardens

5.6.1 Fruit species composition and diversity

Unlike in the wilderness, the homegardens were found to house a limited number of fruit species (15 species) most of which contributed by Rutaceae family and the genus Citrus (Table 4.22). The dominance of Rutaceae was also previously reported at Zeghe garden (Alemnew et al. 2007) and in southern Ethiopia (Belachew et al. 2003) which is perhaps related to the wider adaptation and long history of citrus species in the country. Of course, lime is an integral component of many churchyards and monasteries in Ethiopia. Generally, the lower number of species in homegardens reflects the low level of development of fruit production in the area.

At site level, higher figures for species richness and abundance as well as mean density were recorded at Wangedam. Its lower stocking rate could partly be attributed to its smaller size gardens. On the other hand, despite having lowest mean planting size and fruit density, for the precedence given for coffee, Zeghe appeared the most species diverse. This is because its intermediate altitudinal setup and thus milder climate permit accommodation of fruit species of both the lower and medium elevation ranges (Table 4.23; Figure 4.23). No doubt, the poor species richness, density and diversity at Andassa is accounted for, among other factors, by the poor drainage and low soil fertility, as well as its warmer climate (Table 1.1) that restricts the growing of several species.

Interestingly, however, species of high relative abundance (Table 4.28) for most part paralleled to high relative frequency (Figure 4.26), as well as high density. This centers around five species: banana, mango, guava, papaya and avocado that collectively make up 92.6% of trees of all species. This is indicative that certain species are planted in large numbers and by many gardeners which provides insight into their importance. Of course, bananas, oranges and papayas are also fruit species with a greater share of area and production under permanent crops in Amhara region and similarly in West Gojjam zone except that lemons (probably a misnomer for limes) swap over oranges (Appendix 3). This is instructive as any development intervention in homegardens needs to give precedence to these fruit species. Nevertheless, the highly copious banana occurs at relatively lower frequency indicating its uneven distribution among gardens probably for its high water demand. Zemede and Ayele (1995) suggest that crops of versatile utility and wide ecological plasticity are the most frequently grown crops in homegardens. In the present case, this exactly applies to mango which occurrs both at the highest abundance and frequency in all locations excepting Wangedam. Its lower abundance at the latter could be accounted for the moderately cool temperature at this site that affects its performance, since mango grows best at and below 1400 meters (Sengupta et al. 1996). The dominance of mango can generally be accounted to, among others, its good marketability, relatively long post-harvest life, easy propagation and water stress resistance for its deep root system.

Both relative species frequency and abundance also vary by locality, which can be explained by differences in climatic and soil factors, personal preferences, marketability, water availability, etc. Guava, avocado and papaya occur in higher abundance at Andassa, Wogelsa and Robit (in this order) and so does their frequency (Figure 4.30). The exceptional performance of guava at Andassa is due to its ability to thrive under poorly drained soils without receiving any manure or irrigation (Singh 1995). Known as apple of the tropics for its higher nutritive value, this species is known to be highly remunerative even without much care (Hoda and Singh 1997). In general, the low densities of several species coupled with their uneven distribution raises concern about the viability of populations, and subsequently the sustainability of fruit-based agroforestry systems. Conversely, this is suggestive of the enormous potential and prospect to further diversify and enhance the productivity of several gardens.

5.6.2 Species composition similarities and differences of sites

Species compositions were found to vary by garden and site. While some species are universally recorded across locations others are captured in one or a few gardens and sites. These differences can be accounted for agro-ecological conditions, socio-cultural factors and availability of the crop and land (Zemede and Ayele 1995; Zemede and Zerihun 1997). Generally, Wangedam, Woinma, Arbayitu, Wogelsa and Robit sites tend to be closer in their species compositions (Figure 4.28). The similarity tends partly to follow a pattern of physical proximity of sites that the shorter the physical distance between sites, the higher the species similarity. Environmental and or cultural similarity among gardens and the way farmers manage planting materials, which is from the same seed source, could largely explain species similarities among close-by gardens.

Nevertheless, despite the shorter physical distance in between, Andassa and Zeghe appear to be very dissimilar in their species compositions. As explained earlier, this is rather due to the peculiar environment at Andassa and is suggestive that environmental constraints are more important in species selection than the socio-economic-cultural determinants. Generally, as suggested by Hoogerburgge and Fresco (1993), taking into consideration the type of dominant tree or crop enterprise the majority of gardens production based at, as one criterion for classifying homegardens, Wangedam, Woinma, Arbayitu, Wogelsa and Robit sites can be categorized under one prototype. Apart climate, use of irrigation seems largely contribute to similarities in annual crop species. On the other hand, Zeghe as a coffee-based and Andassa as a sugar-cane based gardening prototype appear quite different from other sites and in between. The implication is that, if not the blueprints, upon fine-tuning similar species, management and recommendation domains can be applied on the five gardens, while Zeghe and Andassa might require their own, which merits further study.

5.6.3 Species and varietal preferences and perceptions of people

The majority of gardeners ranked mango the most appealing followed by papaya, avocado and guava. What is interesting is that, for most part most sought-after fruit species do coincide with most frequent and abundant species indicating that the majority of gardeners are very conscious of the type of species they are growing. Some of these species as mango, avocado and banana are also within the priority list of the Amhara BoARD (Mehari pers. Com.). Even at country level, in volume terms domestic production is dominated by papaya and mango, followed by avocado and banana at par (World Bank 2004). Generally, except at Wangedam, mango is the most acknowledged and favorite fruit for most households that stands first or second in peoples' species preference lists. Another universally adored species was orange which currently for its minimal production the bulk of product for use in Amhara region has to be transported from more than 1000 km away from other parts of the country.

The choice of species is determined to a large extent by environmental and socio-economic factors, as well as the dietary habits and market demands of the locality (Nair 1993; Gajaseni and Gajaseni 1999). In concurrence with this the arguments for preferences of the above group of species in the study areas are centered around their market value, earliness, productivity, continuous production, climatic suitability and water demand of the crops. The sheer dominance of mango is due to economic and ecological advantages as this species grows in wide range of altitudes. Papayas are most preferred for their early and year round fruiting, ease of propagation and low water requirement. Likewise, despite its long gestation period many growers prefer avocado because this fruit has a high market value as it makes the most sought-after juice on its own or punched with other fruits. Generally, taking into consideration species abundance, frequency and growers' preferences, mango, guava, avocado and papaya are key species in the study areas that hold great potential for development.

The maintenance of genetic diversity in homegardens depends on farmer management, the environmental characteristics of the garden and species biology (Hodgkin 2001). In the study areas, most fruit growers use botanically unidentified varieties that are known only by folk taxonomy within which they established their own varietal preferences. Despite the availability of some internationally well known varieties in several species in the country like mango (kent, kiett, tomyatkin), orange (washington naval, Valencia, oval calabrate), banana (Dwarf Cavendish), papaya (solo) and avocado (Hass, Pink, Etinger, Fuerte, Naval, Becon) they have a very limited use in the study areas. This is in line with the suggestion that homegardens inherently compose of crop and animal species and varieties which are environmentally adapted and managed with the locally known husbandry methods (Hoogerbrugge and Fresco 1993). Nevertheless, the perception of many growers is to change most of the species and varieties they are currently growing for better and grafted ones. This tendency of relying on a few varieties and species and abandoning others would actually threaten the genetic diversity and sustainability of the system.

Generally, as seeds are the major form of fruit propagation in the study areas genetic diversity is expected to be high. Thus identifying potential lines of desirable characteristics among the existing cultivars would help develop better varieties. Especially for a sustainable supply and price stabilization varieties of different maturity are needed. Besides, targeted and well-planned introduction of improved varieties and/or of specific characteristics of existing cultivars and other new species that are missing in homegardens can further strengthen the importance of this production system and allow a natural link between conservation and development (Engels 2002). For instance, new temperate fruit species of low chilling requirement as apple, peach, apricot, plums, quince, cherry and pear can suitably imported to areas like Bure for diversification. Similarly, cooking bananas, loquat and passion fruit are potential species which are currently lacking or rarely found in most of the study areas. Rather, the latter two species are seen grown as ornamentals in towns and are hardly known by rural dwellers. Similarly, diversification with shade - loving annuals and other plant species of high payback as *Piper nigrum* at sites like Zeghe and nitrogen fixing species as beans in all gardens would be imperative.

5.6.4 Factors affecting fruit species diversity of homegardens

The study reveled that fruit species and abundance of gardens are correlated with various household socio-economic, cultural and biophysical factors (Tables 5.1, 4.29 & 4.30). Aged household head gardens tend to show greater species richness that can in most cases translate into aged gardens. This may well be because older farmers had had more time to experiment with and retain a greater variety of species (Degrande et al. 2006). Also, the higher the number of resident children the better species richness of gardens is. Often, children number, especially working age children, is related to labor availability

(Hoogerbrugge and Fresco 1993). To this end, about half of the households have five to eight children (Appendix 1) indicating a relatively better labor availability and thus a better species richness. Kindt et al. (2006) similarly reports the relation between species richness and age, years of heading and number of children in Kenyan farms. In addition, male-headed households appear to have significantly higher number of fruit trees than female-headed households. Evidently, apart from their small landholding and low labor capacity, the habitually minimal interaction with the public would not offer female-headed household heads a chance to be conversant with fruit species and varieties as well as values of fruit production as much as their male-headed counterparts would.

Knowledge about use of the species was reported to influence diversity and species composition of homegardens (Das and Das 2005). Concurrent with this perhaps as it helps them get acquainted with higher numbers of species, trained household heads cultivate a higher species diversity than those who are untrained. This is in agreement with the findings of Castiñeiras et al. (2002) in Cuba and is instructive as informed households would be easily amenable for land use change towards agroforestry system. As it is believed to raise peoples' awareness, too often extension contact is counted on enhancing adoptability (Salam et al. 2000; Krause and Uibrig 2006). Although hard to clarify, the negative relationships between access to extension service and diversity index, in the present study, can be linked to the strongly field crops biased extension service that encouraged farmers to maximize on field crops production at the expense of crop diversity.

Plant species composition is also influenced by market demands so that less diversity would be expected in close-to-market gardens (Kehlenbeck and Maass 2004). However, the present study exhibits another trend. Both number of species and fruit trees appear to vary inversely with market distance which concurs with (Wezel and Ohl 2005; Snelder et al. 2007) but contrasts the hypothesis that remoteness from urban centers increases species richness. This can be explained by a broad range of factors such as ignorance of food value and lack of experience with fruit tree cultivation, poor access to planting material, poor transport and market, etc. in remote gardens. As a result, farmers will be forced to give precedence to production of staple food crops. This suggests that gardens further from the markets are less exploited. Besides, as gardens are located far away from residence, their species richness declined and recorded a lower diversity. This might be related to ease of access for management as distant gardens might not receive the necessary care and management.

Table 5.1: Characteristics of explanatory variables used in garden species richness and diversity analysis

Variable	Range	Mean	Description
Gender of household head: 0: Female; 1:Male	0-1		85% are male; 15% female
Age of household head (years)	18 to78	43.4	
Number of years the family headed(years)	1 to 51	23	
Education level of the head (school years)	0-12	3.2	29.3% are illiterate
Training: 0: not trained ;1: trained	0-1		36.1% are trained
Number of resident children	0-12	4.9	3.4% do not have children
Extension contact: 1. Yes; 2. No	0-1		80.3% have contact
House type :1: Iron roofed ; 0: Grass thatched	0-1		90.5% have iron roofed houses
Garden distance to market (km)	2.0-27.0	12.37	
Garden distance to road(km)	0.003-7.5	1.82	
Garden distance to water source(km)	0.001-3.5	0.9	
Garden distance from a house(km)	0.001-2.0	0.15	
Altitude (meters above sea level)	1600-2040	1818.9	
Garden size (ha)	0.03-3.0	0.44	

Apart from the factors mentioned above, religious and cultural beliefs, customs, and taboos of the villagers (which are not included in the analysis) would certainly influence the diversity and composition of homegardens (Kumar and Nair 2004). In Ethiopia, including in the metropolis, up until four decades ago fruits were sold only at hospital gates as they were meant for sick people and children (Seifu 2003). Likewise, in the present study areas, where people have a long-established tradition of cereal-based diet, so is familiarity with fruit production and consumption very diminutive among the majority. Equally important is that fruit growing is a long-term venture requiring a high investment and a high recurring expenditure. Hence, ordinary farmers are unable to muster such a high investment required that might again discriminate fruit species richness and diversity among the different household capacities.

In the study attempt was also made to explore the relationships between garden size and fruit species richness and diversity. The mean number of species tends to be greater on large gardens compared to medium and small gardens. This is in agreement with Trinh et al. (2002); Ahmed and Rhaman (2004) and Das & Das (2005) and happens because more space gives more room for different species and allows multipurpose use of garden areas (Drecher 1997). Also, the number of fruits per garden progressively increases from small to large gardens which concurs with the findings of Kindt et al. (2006) and Albuquerque (2005). As suggested by Salam et al. (2000), when main source of income is agriculture it negatively affects farmers' tree-planting decisions as it would naturally be their priority. Hence, it is inferred that in small homegardens farmers engage in a diversified portfolio of assets that reduce vulnerability for which they make trade-offs between fruit trees, annual crops and animal production, and open space for various operations.

Quite the contrary, however, consistent with Ahmed and Rhaman (2004); Trinh et al. (2002) and Mohan (2004), the density of both species and trees is higher in smaller gardens than in both medium and large gardens (Table 4.24). This implies that small gardens try to maximize production by increasing the number of species and fruits per unit area. Conversely, it might mean that large gardens keep only few trees and concentrate on staple crops. Moreover, species diversity and evenness is relatively low in large gardens (Table 4.24) which is in agreement with Drescher (1997). This again implies that in large gardens people give more focus on staple crops that would offer them a better profit because of the economies of scale and would tend to grow fewer species of higher importance disproportionately in large numbers. Moreover, it means that in small gardens farmers do not sacrifice species diversity in favour of increasing production of a particular crop (Mohan 2004) and for the limited space they grow species evenly. Further evidence was drawn from the higher species similarities between small and medium gardens confirming that a relatively smaller land size difference does not restrict species composition.

What is more, it is evident that large stature fruit tree species are more frequent in large compared to smaller gardens (Figure 4.25). These differences are certainly attributed either to space availability or perceived value of the fruit. For instance, as it requires more space banana is dominant in large gardens. On the other hand, while it is space-demanding avocado is equally or more grown in small and medium rather than large gardens possibly for its high economic value. This suggests that while species abundance is highly affected by land size, species selection is not greatly so.

With respect to physical factors, gardens at moderately higher altitudes tend to have higher number of species and higher diversity to those in the lower altitudes. This can be explained by the capacity of the high altitude areas to accommodate a broad range of species from both lower and medium elevations for their favorable climatic and soil conditions. In total, the many factors that shape farmers decisions about tree growing mean that support strategies must be carefully differentiated.

5.7 Support services, fruit utilization and income in homegardens

5.7.1 Source, availability and quality of fruit planting material

Access to the necessary inputs for gardening from a local, sustainable source is an important element for successful gardening. Sadly enough, except the modest efforts by the BoARD no institution or enterprise is known to multiply fruit planting material in the study areas and in the region in general. Hence, planting material supply for the major part comes from government nurseries and in a few cases from own source or purchased, bartered or wildlings. Nonetheless, irrespective of its source the quality of planting material is generally mediocre and its supply far from adequate. In this regard, encouraging the establishment of farmers' private and community nurseries and training would appear imperative. However, this will work if the existing planting material supply strategy of BoARD could change from low-cost or free supply to competitive prices. Otherwise, private nurseries will undoubtedly be discouraged. This has been clearly documented in India where because seedlings were distributed free and indiscriminately, a heavy monetary loss was incurred due to poor seedling survival (Mahapatra and Mitchell 2001).

5.7.2 Fruit propagation, tree and cultural management

Seed remains a major mechanism of fruit propagation especially for mango, guava, papaya and avocado. However, as most species are cross-pollinated and highly heterozygous this method of propagation is bound to yield in inferior quality. For instance, propagation of mango by stones leads to variability in the progeny and is a limitation for commercial orcharding especially with monoembryonic varieties. In guava too, raising of plants from seed is not desirable since seedling trees differ greatly from the mother-plants (Singh 1995). This is instructive that vegetative methods of propagation are necessary for getting true-to-type plants. This is important not only to avoid heterozygosity but also reduce the juvenile period. For instance, grafted mango varieties start bearing from the age of five compared to ten years in seedlings (Singh 1995). But, if seeds have to be used for mango propagation, choosing polyembryonic seeded varieties would be advantageous (Morton 1987).

It is also important that farmers receive adequate information about planting procedures and techniques of fruit production to augment their indigenous knowledge with up-to-date technologies. In the study areas, seedling and tree management practices are only minimally practiced which is partly due to the gardeners' unfamiliarity with most of the fruit species. This is because the majority of fruits in Ethiopia are introductions that their management is new to the people (Seifu 2003). As a result, the homegarden agro-ecosystem is generally operated through the active use of indigenous knowledge, practices and skills (Zemede

2001). If there is at all little knowledge shopped, it must be the one learnt in the middle ages by Ethiopian churches and monasteries from European delegates of that time and from monks who made a pilgrimage to Jerusalem (Edwards 1992). Neither is the local wealth of talent and experience receiving the necessary support from experts. Currently, BoARD is a source of knowledge for majority of farmers albeit inadequately. Because of this fact, in the majority of cases fruit crops do not receive the necessary inputs, cultural and tree management.

On the other hand, homegardens are often reported to receive a heavy application of animal manure and the soil is more fertile than in the larger agro-ecosystem (Hoogerbrugge and Fresco 1993; Shrestha et al. 2002). It is indeed the case in the study areas that most gardens receive manures of different types. Especially at Andassa farmers intensively apply chicken manure and rape cake. However, Drescher (1997) cautions that chicken manure often causes burning of the plants. In studies in connection to livestock feed the *in vitro* mineral availability of rape cake was reported to be good in terms of Ca, Mg, Fe, Mn, Zn and Cu (Kabaija and Little 1989), which is suggestive of its role in providing both major and micro-nutrients. Unfortunately, however, due to the growing shortage of fuel wood the use of animal manure in gardens has decreased in recent years, which would hamper productivity as well as polycultural garden production system.

To all intents and purposes, synthetic fertilizers are virtually not used in homegardens. This is consistent with reports from other countries (Shrestha et al. 2002; Kehlenbeck and Maass 2004; Ali 2005; Gebauer 2005). Besides, despite the fact that composting is a technique widely used in different parts of the world, perhaps for lack of awareness on its value and method of preparation it very rarely used in the study areas. In all, the absence of synthetic fertilizers and a heavy dose of manure application are suggestive of the better fertility status of homegardens. In addition, a high litter biomass and diverse litter composition contribute to a high efficiency of nutrient cycling that ensures minimal nutrient export from the system (Gajaseni and Gajaseni 1999; Kumar and Nair 2004) while the accumulated organic matter could increase cation exchange capacity and reduce leaching of nutrients. This is clearly illustrated by the Zeghe site which, due to its high vegetation cover, appears to be a relatively more fertile site rich in total nitrogen, organic carbon and available phosphorus (Table 4.31). On the contrary, Andassa is very poor especially in total nitrogen for its low vegetation cover and thus low degree of soil litter cover. Besides, the dominantly clayey soils of a near neutrality pH range signify that homegarden soils are within favorable soil fertility conditions. In sum, compared to the outlying farms homegardens in the study areas have quite a good soil fertility status. This is consistent with Drescher (1997); Gajaseni and Gajaseni (1999) and

Shrestha et al. (2002).

Furthermore, although several species are succumb to the scourges of diseases and pests, the culture of pest and disease control is not well developed. Pesticides are applied very minimally and only in connection with control of chat pests. Neither is herbicides used for weed suppression. This is consistent with reports of Ali (2005). Of course, the capability to avoid dependency on imported inputs is the most distinct characteristics of traditional homegardens (Abdoellah et al. 2002). Therefore, the produce in homegardens is clean contributing to environmental protection as well as public health. Besides, uses of home generated inputs at no or low cost would also make homegardens economically efficient and sustainable. In total, the findings suggest that the homegarden system can sustainably be developed with low level of external input that can ultimately help growers to fetch premium prices through marketing organic produce.

In many environments, water for homegardening is likely to be the most important consideration after land and it may be even scarcer than land and more expensive to supply during the driest months of the year (Mitchell and Hanstad 2004). In the study areas, because there is a marked dry season nearly for half of the year (Figure 3.3), in the majority of cases fruit growing is inextricably linked with the availability of supplemental irrigation. As a result, most fruit growers are those residing following river courses or have access to irrigation canals near-by.

Several potential water sources remain less exploited in the study area. For instance, while availability of water during the dry season could be guaranteed from the ground water source, except a little at Robit site this source is hardly utilized. Ground water is a chief source of water for gardening in several other countries. For instance, in Soqotra island of Yemen homegardens are mostly maintained by wells (Ceccolini 2002). Rainwater harvesting is another potential and affordable means of capturing, storing and applying water for homegardens that is again very much overlooked. However, some species like guava, papaya and mango can also be grown under only rain fed conditions provided that some supplemental water is given during their establishment and early stages of growth. Besides, to reducing homegarden demand for water and attain huge gains in the efficiency of use, strategies like terracing, trenching, deep mulch and surface mulch including living mulch and ground cover creepers can be resorted to as well (Mitchell and Hanstad 2004). On the other hand, in areas like Andassa where water logging is a problem, canopy layers, raised beds and drainage canals may help to prevent flooding water overflow. In general, the study conveys the need for exploration of alternative sources of water and improved water management practices for effective fruit production.

5.7.3 Pattern of planting and spacing

The majority of sample households follow a row planting pattern of fruits while still a good number of them plant in a randomly fashion. In areas like Wangedam most gardens seem grow fruits in chaos which has come about for the filler planting practice in an attempt to replacing the old stock to the an otherwise initially row planted fruits. Consequently, gardens become too dense and the planting pattern changes from row to mixed resulting in a pattern similar to what is known as Quincunx planting. Sometimes, pattern of planting also depends on the type of fruit. For instance, guava is mainly planted haphazardly which might be related to its natural regeneration from which wildlings are retained where they are naturally grown. This is in agreement with what has been reported by Zemede (2001). On the other hand, looking at only fruit crops, tree spacing of the majority of gardens tend to be optimal. Although spacing depends on varietal characters, soil fertility status and other factors, the spacing used for some fruits as mango, avocado and orange is more or less in conformity with spacing used in other countries like in India (Kunte et al. 1997). Nevertheless, in some sites fruits are grown crowded which is exacerbated further by intermingling of other crops. Among some of the possible measures that can be taken to modify the vertical layer for optimal space utilization are high-density orcharding as in citrus and use of dwarfing rootstocks as in mango. In India, double-grafting has been found to dwarf mango trees and induce early fruiting (Morton 1987).

Given that the right species mixes are maintained, in view of the long gestation period of several fruits, inter-cropping and planting of filler trees is reasonable in order efficiently to utilize the various niches. From time zero to the final developmental stage of the homegardens, there are many niches that can be filled by agricultural plants. Depending on the location, currently the most common types of intercrops are fruits with perennials as hop, chat and coffee. The herbaceous stage is the shortest stage lasting a year or two to three years after which yields decline because of shading, low soil fertility and competition from perennials. In such a situation, short duration species like papaya and bananas that begin to produce within the first year can be integrated within large fruit and non-fruit trees. These species can create the microclimate conditions necessary for viny species (De Clerck and Negreros-Castillo 2000). From about five to seven year on, fruit and timber tree species bear fruit and shade out perennial shrub crops, particularly those in the low shrub stratum. In such a situation, tuber crops such as taro, cassava, yams and sweet potato can be grown with relatively less care as understory species in partial shade and can yield carbohydrate-rich produce (Fernandes and Nair 1986) and of course invariably coffee. Pineapple and ginger could also be cultivated in the understory (De Clerck and Negreros-Castillo 2000). Vines that use tendrils for climbing, as do the cucurbits and gourds, can be integrated in early stages of development due to their inability to grasp larger diameter stems. Especially incorporation of leguminous species of annuals like beans and perennials *S. sesban* as temporary shade or fence could benefit a lot. In a nutshell, adoption of more systematic tree planting designs and careful species selection may reduce the difficulties of using homestead land for fruit tree planting simultaneous to other uses.

5.7.4 Fruit seasonal availability, utilization and sale

Because of slight variations among sites, varietal differences and the level of management, there appeared a constant supply of fruit produce of one kind or another through out the year (Figure 4.33). Typically, species as guava, papaya and banana are available almost year-round. Nevertheless, to achieve higher productivity in fruits like guava it would be better to take only one crop a year that can be accomplished like through withholding water (Singh 1995). For instance, withholding irrigation around January could result in shedding of fruits that bear fruits in March to May due to water stress by heat. Fruiting of other species, among others, mango, avocado, orange and peach concentrate from about March in the dry season to the middle of main rainy season which coincides with the time of crucial food and nutrient need. On the whole, the year-round availability of fruits could help to diversify sources and types of micronutrients in the daily diet.

Nevertheless, a great portion of the produce is sold than consumed and thus there is a danger that the dietary role of fruits for growers may be lost that would also impact health. However, the rarity and insignificant role of fruits in peoples' diets is not peculiar to the study areas rather it is a universal phenomenon in Amhara region (BOA 1999) and the country at large (Westphal 1975). Of course, this is contradictory to reports on role of homegarden products in several part of the World (Ali 2005; Bennett-Lartey et al. 2001; Wezel and Bender 2003). The low consumption of fruits is partly attributed to ignorance of their nutritional value and method of preparation, need for cash and more importantly dietary custom of people. Experience shows that counseling to change eating behavior is an important component of food-based strategies (Talukder et al. 2001). This is suggestive of the need for nutritional education and social marketing to achieve sustainable behavioral changes of the community on fruit consumption. Besides, fruit recipe development and cooking demonstrations may need to be incorporated into a garden development and promotion plan.

Fruit prices are generally low and vary to some extent by site, market and most importantly season. In major fruiting seasons, prices drop by at least 0.50 to 1.0 birr while in the lean periods they sell better. Low fruit price is further caused by lack of processing plants. Some fruits like lime that are abundantly available year-round have a processing potential. At country level, the Merti processing plant processes several fruits like orange, lime, lemon mango, grapefruit, guava and strawberry into several products like marmalade, juice, nectar, jam, squash and citric acid (Seifu 2003). Also, household processing of garden fruits and vegetables as drying and canning could increase their market value and ensures a year-round supply (Marsh 1998). Besides, strategic growing of different maturity group varieties could solve seasonality problem and thereby seasonal market gluts.

In general, as it stands today because of the low productivity of most fruits coupled with the near to the ground prices fruit production remains not rewarding for the majority of growers. Nonetheless, few households with well-developed homegardens have in fact enjoyed a speedy wealth status change and have become well heeled out of fruit production. Some of them have become a role model for the community that their activities are televised, their gardens visited by prominent government officials and villagers and awarded patriotic prizes in recognition of their exemplary work that might in turn motivate them and others to emulate it. This is suggestive that promotion of fruit production and homegardening in general could have a substantial role in mitigating food insecurity and taking away people out of poverty.

5.8 On the wild-domesticated fruit continuum

In the study areas, because people have already reached almost all possible habitats, the largest system of the working landscape rather sieges the remaining forest patches. Hence, what is in the ecosystem is in reality in and around people's habitations. Sometimes it gives even the impression that the role of agro-ecosystem and wilderness has been reversed; villages more look like forests than the natural forests *per se*. What follows is that there is no hard and fast line demarcating the place of some fruit species looked upon wild between wilderness and agro-ecosystems. They are rather found in the homestead-farm-forest continuum except that depending on the level of human intervention their frequency of occurrence and their present position in the continuum varies by species and locality. According to Zemede and Mesfin (2001), their position can be disclosed by their sporadic use, purposeful planting and harvesting, marketability and proximal growth with gardens and living quarters. By and large, among species regarded wild *M. kummel, D. mespiliformis, Ficus* spp.*, F. thonningi, C. africana, Z. spina-christi, R. abyssinica* and *S. guineense* dominantly occur in the semi-wild state and are thus close to domestication. For instance, though primarily for their non-fruit utilities seven wild fruit bearing species were recorded in the homegardens.

At the other end of the spectrum, while they are domesticates species like citrus and guava are also found feral. Of course, citrus species have been grown as back as 16th century in monasteries in northern Ethiopia (Edwards 1992) from which they might have escaped into the surrounding forests. The wilderness in guava might be for its easy dispersal mechanism like by birds. Similarly, Zemede and Desalegn (2004) recorded 34 species occurring both in the natural habitats and homegardens in two zones of Ethiopia. Generally, the swinging of these fruit species between domesticated and wild conditions and featuring in nature-culture continuum is important from the standpoint of conservation and genetic diversity maintenance and instructs the need for conservation of the natural ecosystem for the wellbeing of the agro-biodiversity.

5.9 Trends, challenges and prospects of fruits

5.9.1 Population trends, constraints and prospects of wild fruits

As predicted, the population of wild fruit trees in the landscape is generally in a serious decline of incomprehensible scale, which is primarily accounted for human population pressure and subsequent severe forest degradation and concomitant agricultural expansion. This concurs with reports of Kebu and Fasil (2006) in South Ethiopia. Apart from physical removal of the wild fruit species along, forest clearing also modifies or destroys the habitat of those species whose regeneration is favored by the shady moist ecology. Furthermore, as forests are cleared liana species like *Rubus* spp. could disappear or decline to fruit, as they will be devoid of support for growing and fruiting. Importantly, in the event of the current free grazing system a perceived decline of wild fruit trees is also sourced from livestock population pressure especially goats. Apart from trampling damage by stray animals to seedlings, the increased voracity of cattle in recent times has culminated in indiscriminate feeding of many species' seedlings and hampered natural regeneration.

One of the consequences of habitat loss, fragmentation or degradation is that large number of wild species will be threatened with local or total extinction. In this regard, on unprotected sites especially at Adiarkay, *X. americana* is almost to become a has-been species. This is amply demonstrated by scarcity of young and middle aged classes of trees which would result in scarcity of effective size breeding populations. It was further noted that it is not only the population of wild fruit trees, but also their fruiting load has recently declined. This might be attributed to climatic change especially the recurrent drought and perhaps the elevation in temperature that affects pollen production and fertilization. In contrast to small life forms of plants, many fruit tree species are less resilient to agro-ecological changes, as they may take many years to re-grow to maturity (Scoones et al. 1992). In addition, sex ratio imbalance in dioecious species for the chance cutting of more female trees might lead to inadequate pollen production and could impair pollination and fertilization. It is also possible that the accelerated rate of soil nutrient depletion influenced productivity of trees.

The present study, however, disclosed that some ecological niches are serving repository of wild fruit species and there by maintaining their population at an adequate level. In this regard, the role of the Ethiopian Orthodox monastery ground and churchyard forests that are estimated at more than 35,000 and some of which occurring at the remotest point of the rural Ethiopia (Teklehaimanot 2004a) is noteworthy. They are comparable and play a similar role to what are known as, according to FAO (1999), sacred groves or scared forests. In these sites, tree failing, burning, cultivation of crops is prohibited by local religious taboos. As has been discussed previously, these are areas where fruits have been recorded as back as 16th century. These places exemplifying what is termed as vernacular conservation might not contribute directly to farm household income but have a safety role in providing reserves of useful plants, a store-house of diversity and thereby provide a reserve of germplasm for enhancing local agricultural productivity (FAO 1999). They can also serve a focal point to widening up wild edible fruit species agroforestry in their surroundings. However, in recent times the irresistible poverty overriding peoples' cultures, traditional rules are being broken down and legally or illegally compounds of some sacred areas tend to be accessible freely or in places like *Armadega* through a little local levy known as "*Emeha*". This would endanger the wild fruits and other useful flora and fauna as well.

In sum, pertaining to the population trend of wild edible species some generalizations can be made. First, most species occurring in unprotected landscapes are at a dramatic decline. Second, those wild fruit species located in the protected sites like churches and monasteries forests are in a better status but their relevance can only be seen in terms of conservation rather than utilization. Such species, as suggested by Johnson (2002), can be regarded as nutritionally extinct as they no longer contribute to local household food intakes though they could be ecologically stable. Thirdly, those species frequently integrated in farms, no matter what the purpose of integration may be, are again in a better position seen at tree population aspect but not fruit production. Therefore, increased priority may need to be given to redress those species residing in unprotected wilderness.

Seen at a system level, as clearly visualized on a rich picture in figure 4.35, several agro-ecological, economic and socio-cultural factors interact to affect wild fruits development. Factors like policy and global climate change do also influence the system externally. Moreover, it has also human and institutional dimensions that several stakeholders and organizations are interacting variously. This suggests that interventions aimed at wild fruits development may need to consider such interactions and interdependences among several factors and stakeholders.

Despite several limiting factors and the low level of farm integration, however, recently there are some positive developments that seem encourage or expedite the use and integration of wild fruits in the farming systems. Evidence is building that driven by the ever-increasing demand of fruit trees for various purposes there is a recent awakening of their benefits and appreciation of their decline. As a result, though not in full swing some are already taking up steps to changing their management practices, for instance, towards pollarding and or lopping *in lieu* of cutting. Few others have started organized planting of some species signifying that the scope of domestication is bright. These attitudes of the farmers may need to be harnessed for adoption of these species in agroforestry systems. Moreover, recently some important measures have started to take place by the government that indirectly creates a favorable framework for their domestication. These include assurance of land security through entitling use-rights, permit issuance requirement for the cutting of some high value species and restrictions imposed on wood smuggling on species like *C. africana*. These are important steps forward to sparking strong interest on farmers and enhancing trees and there by wild fruits in the landscape. In addition, as the country steps into its third Millennium in 2007/08, citizens have pledged with great enthusiasm to plant trees under the watchword "*two trees per head in 2000* " that especially focuses on indigenous species in which there is a likelihood that indigenous fruit bearing species might also be embraced. In total, in the event of worsening climate, the ability of wild fruit trees to withstand harsh conditions is expected to be of over-riding importance and a major factor driving their protection and domestication.

5.9.2 Production trends, constraints and prospects of domesticated fruits

In homegardens, depending on the type of species and varieties, constrains and opportunities, fruit production is both at increasing and decreasing trend. Depending on the locality, orange, papaya, avocado, lemon, sour orange and local peach tend to decline while guava and mango seem at an increase. The later might be because of the ease for their propagation from seeds and wildlings. On the other hand, it was learnt that in recent years, the majority of households are undergoing changes in their gardens. These are manifested by increase in garden size and number of plants as well as a change in the pattern of planting from random to a row. On the contrary, for reasons of wild animal problem, low productivity and marketability some farmers tend to shift either to wild animal immune fruit species or totally defer fruits in favor of sugar cane and chat. The later instructs that making fruit production more paying is a necessary condition for the continuance of fruit growing in the homegardens. One can draw a lesson from the experiences of the Gamo people of south Ethiopia where they have replaced staple crops with mango, papaya, banana and avocado for the high economic return from the later (Belachew et al. 2003).

Generally, the domesticated fruits production system in the study areas is constrained by various bio-physical and socio-cultural and economic factors (Figure 4.34). Among biological factors, diseases especially *P. angolensis* and *Phytophtora* species are threatening orange production to the point of abandonment. The later of which is aggravated by the poor soil drainage, and to a certain extent can be combated with the use of resistant rootstocks as Macrophylla and high budding while proper irrigation can restrict its spread (Singh 1995; Seifu 2003). Wild animals represent one of the most notorious and destructive fruit production problems. Mistletoes especially Loranthus is devastating several fruits resulting in the disappearance of the local peach which its incidence could be reduced through mechanical removal by cutting out completely from its base deep in the branch before flowering.

Among socio-economic constraints, access to improved varieties is a universal problem suggesting that supporting growers through provision of appropriate varieties might need to be kept more to the forefront. Access to suitable land is perhaps the most fundamental factor especially for youngsters who are very enthusiastic of fruit production but did not have land as most of them were under land-entitling age during the last re-distributions. Conversely, most elderly people who currently own land are not interested to engage in fruit production as their relatively large landholding satisfy them their staple crop demands or do not have labor or lack the modern day business mind. Neither they are willing to rent their land out to landless youngsters for perennial crop production for fear of the long gestation period and thus land insecurity. Water is another grave problem for fruit production which is worsened by the inability to see other potential water sources like ground water. Besides, for the knowledge gap handicapping proper cultural practices most farmers generally care their fruits very low. Either because they do not follow properly the advices and technological recommendations or do receive little technical support. Neither are fruit crops receiving the necessary research support.

Cultural acceptance of homegardening is equally important (Mitchell and Hanstad 2004). Some growers are obsessed that however large the benefit from homegardens would be, they can not at any rate parallel the benefit from staple crops grown in arable fields. As a result, they undermine fruit production and gardening in general and want to stay largely bonded with arable farms.

Perhaps the most formidable threat to fruit production appears the growing rivalry in land use between fruits and other cash generating crops mainly chat, hop and coffee and to some extent sugarcane. That these groups of crops fetch a high rate of return they have got a high fervor among the gardeners than fruit crops that have a long gestation period and currently a low price. Similar situations were reported in Wello homegardens (Conway 1988). Further evidence is also obtained from the total area under stimulant crops in west Gojjam zone, where hop and coffee respectively share 50.51% and 45.70% of the area and 82.71% and 15.85% of production. Similarly, of the permanent crops in Amhara region, stimulant crops (coffee, chat and hop) have a large area share (86%) and production (74%) compared to fruits, 9% and 17% in that order (Appendix 3). As a result, homegardens tend to eventually evolve towards commercial production that would scale down garden production into a greater or full share of a few most profitable species and lead to a decline in fruit production. Sooner or later, this will lead to a reduction in garden floristic diversity which is likely to affect the sustainability of the production system (Abdoellah et al. 2001). This suggests that keeping fruit production more remunerative is a necessary condition so as to compete with other enterprises so that farmers could reap the rewards of their efforts and fruit production is sustained.

Given the above conditions, however, it is quite encouraging that the majority of sample gardeners project to expand fruit growing through taking various measures. This includes establishment of own nurseries, more water wells dug, buying motor pumps, relocating gardens close to water source, introducing new fruit species and varieties, renting in additional land, etc. Hence, given the increased curiosity of farmers to expand fruit production, it should be possible to harness these positive attitudes to a strategy that creates favorable environment to supporting and building upon their efforts.

6 Summary and conclusion

Species composition and diversity

Notwithstanding their marginal environment and poor vegetation backdrop, the study areas are endowed with several wild fruit bearing plant species that inhabit diverse habitats and niches in the nature-culture continuum and vary to a large degree by altitude and site. Most of the species occur in the low to medium altitudinal ranges rather than in the highlands which can be explained by the extremely harsh climate and high degree of anthropogenic influence that has culminated in severe deforestation. As a result, sites representing lower elevations and for the most part sharing overlapping ecological niches, Bermariam, Adiaregay and Kurar, show a greater number of species compared to the other sites.

Albeit primarily for non-fruit utilities, some 17 species that are perceived as of greater use occur at different niches in the realm of anthropogenic ecosystems, which indicates that a low level of domestication is underway. Nevertheless, only a few species of good virtues and diverse utilities like *Z.spina-christi* occur in relatively higher abundance and frequency. It was also found out that sites that have a higher species richness in the overall landscape by and large show a better farm integration of wild fruit species and higher diversity. Species choice in the different agricultural niches seems generally related to relative importance and compatibility. Overall, farm edges appear to be the major source of wild fruit bearing species, especially for those regarded as having low importance and utilities.

The propensity of farmers to domesticating wild fruit species is negatively influenced by the free availability mindset, illiteracy, land shortage and the occurrence of farms on gentle slopes. Likewise, both the level of domestication and the number of species and trees in farms progressively and then sharply dwindle as altitude gets higher. On the other hand, size of landholding appears to have a positive relationship with farm integration, as well as abundance of wild fruit tree species in farms, which is related to the economies of scale explanation that a farmer with more land can accommodate both staple crops and trees.

The wild fruits domain of the study area appears generally rich as it constitutes of 46 species. Age appears to be the single most important factor responsible for knowledge variations of wild fruit species, where youngsters are more knowledgeable to elders. This wealth of genius of wild fruits on the part of the younger generation is suggestive of the perpetuation of indigenous knowledge. *C.spinarum*, *C.africana, F.sycomorus* and *Z.christi* appear to be the most salient species of higher consensus, which would translate into prototypical to wild fruits domain and more significant to the informants.

In homegardens, there has been a greater tendency and surge of fruit tree planting in recent years that seems driven by the commencement of aggressive agricultural extension service. Nevertheless, there is a contrasting development of homegardens among the different sites which is mainly related to the level of access to water. Nonetheless, area allotted to homegardening is a mere fraction of the total landholding and varies from site to site, whereby the largest allocation was recorded at Zeghe. The low garden land allocation is due partly to the severe land shortage so that arable cropping alone cannot fully provide households with enough calories because of which garden land is additionally used for field crops production. This enlightens that the promotion of homegardens as fruit or vegetable gardens alone is likely to be unsuccessful.

The homegardens are chiefly managed in an agroforestry approach maintaining polycultural production. Some 104 species of trees, annual and perennial crops along with animals of different sorts are inextricably assembled temporally and/or spatially, where crop mixes, extent and intensity vary among gardens and sites. Besides, albeit with low visibility, the agroforestry components are stratified vertically into four strata and horizontally into three management zones, where most fruit trees dominantly occupy the third layer and the second zone of horizontal structure.

However, unlike the wild fruit species, the study areas house only 15 fruit tree species that vary by garden and site. The Wangedam and Andassa sites show the highest and lowest species richness, respectively. Zeghe is the most species diverse site for its intermediate altitudinal setup that is favourable to accommodating fruit species of both the lower and medium elevation spectra. The poor species richness, density and diversity at Andassa are accounted for, among other factors, by the poor drainage, low soil fertility and warmer climate that restrict the growth of several species.

Species richness of gardens increases with the age of the household head and years of heading, training, children number, garden distance from the road and altitude, whereas garden distance from marketing center and residence have the inverse effect. Garden species abundance positively correlates with garden size, being a male household head and number of children, while it has again an inverse relationship with market distance. Gardens of trained household heads or located far from the road or at relatively higher altitudes tend to maintain higher species diversity, while those who have access to extension service and far-off residence gardens show low diversity.

The number of species and trees tends to be greater in large gardens compared to medium and small gardens, while the reverse is true for species density, diversity and evenness. This elucidates that in small gardens farmers engage in a diversified portfolio of assets that reduce vulnerability for which they make trade-offs among different components. It might also mean that farmers do not sacrifice species diversity in favour of increased production of a particular fruit species. Generally, while species abundance is highly affected by land size, species selection does not seem so.

Banana, mango, guava, papaya and avocado are species that occur in higher relative abundance, frequency and density in homegardens. Mango is the most sought-after species by gardeners, followed by papaya, avocado and guava. This provides insight into the importance of these species and is instructive insofar as any development intervention in homegardens needs to give precedence to them. On the other hand, the low density, frequency, abundance and uneven distribution of several other species is suggestive of the enormous potential and prospect to further diversify and enhance the productivity of gardens.

Species compositions vary by garden and site. Generally, the Wangedam, Woinma, Arbayitu, Wogelsa and Robit sites are composed of more or less similar species and fall under one prototype. This implies that with a little fine – tuning, similar species, management strategies and recommendation domains can be used on these five gardens.

Seedling and tree management, cultural practices and support services

Seed remains the major mechanism of regeneration for both wild and cultivated fruits alike, which is bound to confer inferior yield and quality. As a result, the quality of the planting material is generally mediocre and its supply far from adequate. This underpins the need for vegetative propagation for getting true-to-type plants and reducing the juvenile period, especially to rapidly multiply and use the large genetic diversity in wild species. Also, seedling and tree management practices are poor, which can mainly be attributed to the growers' unfamiliarity with most of the fruit species. Neither is the necessary technical backstopping obtained from research and extension.

As a result of continuous enrichment with manures of different sorts, most homegardens fall under favorable soil fertility conditions. This, however, varies by site as gardens at Zeghe and Andassa have high and low soil fertility, respectively. Neither synthetic fertilizers nor pesticides are applied. Generally, these findings tip off that the homegarden system can be developed sustainably with a low level of external input that would ultimately enable growers to fetch premium prices through marketing under the tag of organic produce.

On the other hand, as there is a marked dry season nearly for half of the year, fruit growing is inextricably linked with the availability of supplemental river-based irrigation water. But several potential water sources like ground water and rain water harvesting remain unexploited.

Fruit utilization and income generation

Both wild and cultivated fruits are available year - round and have a great potential to contribute to food and nutritional security at times of most need. Indeed, some wild fruit species were found to be well laden with important nutrients. Nonetheless, the current level of consumption is very low and fruits are rare and play an insignificant role in the diets of growers. People's cereal - based dietary custom, ignorance of nutritional value, local taboos and urgent cash need make up a large part of the explanation. This is suggestive of the need for nutritional education and social marketing to achieve sustainable behavioral changes of the community towards fruit consumption.

By and large, except for a few species, food value appears to have a subordinate role on the part of wild fruit bearing species. Rather, they are exploited for various non-fruit utilities. Fuel wood, construction and fence are the major the use categories, while *C.africana, T.indica* and *Z.spina-christi* emerged as species of copious utilities. While the multiple uses demonstrate the continuing importance of these resources, the high pressure could also pose them a threat.

The study also revealed that some wild fruits and several cultivated fruits are sold in local markets and generate additional income. Nevertheless, trade flows, prices and incomes are generally very low, which is mainly accounted for by seasonal gluts, lack of processing facilities and random entrance of several casual vendors. Promotion of value-adding techniques and strategic growing of different maturity group varieties could partly lend a solution.

Fruit population trends and constraints

The population of wild fruit trees in the landscape is generally in a serious decline, which is primarily accounted for by human and livestock population pressure and subsequent severe forest degradation and concomitant agricultural expansion. However, some habitats as monastery ground and churchyard forests play an important role in maintaining endangered species at a satisfactory level. In homegardens, while orange, papaya, avocado, lemon, sour orange and local peach tend to be on the decline, guava and mango seem to increase, probably due to the ease of their propagation from seeds and wildlings.

Overall, fruits both in the wilderness and from cultivated sources are constrained by several agro-ecological, economic and socio-cultural factors. Diseases, wild animals and tree related constraints such as low pulp content, low productivity, long juvenile period and higher perishability are major limitations in both systems. Fire and recurring drought severely affect the regeneration of wild fruit species. Access to suitable land and water remain the most decisive factors for fruit production in homegardens. Likewise, lack of quality planting material is a major bottleneck for wild and domesticated fruits alike. Cultural factors, overridingly negative connotations with wild fruits use, are at the root of their disregard to a significant degree.

Finally, a growing rivalry in land use between fruits and other cash generating crops (mainly chat, hop and coffee) in the homegardens presents another major difficulty. For the perceived high benefits farmers give precedence to the latter crops rather than fruits which have a long gestation period and currently low price. This reveals that keeping fruit production more remunerative is a necessary condition.

Recommendation

Given that a multitude of factors are interacting in restraining fruit production, this calls for integrated intervention in order to deal with the problems effectively. Thus, future development of fruits needs to draw on the identified constraints and opportunities to re-enforce farmers' present endeavors and build upon them for improved efficiency and productivity of the system. Therefore, among others, the following research and development actions are suggested:

- Research is warranted on detail analysis of plant associations in the homegardens for a better knowledge of the ecological and economic compatibility of different plant species so as to develop a sustainable fruit-based agroforestry system. This should result in the development of homegarden kits prescribing model planting designs with the right mix of specified fruit species and varieties and other components of the system.
- To ensure wider knowledge, acceptance and achieve sustainable behavioral changes on fruit use, rigorous promotion and mainstreaming among the general public through e.g. public awareness campaigns, integration into school curricula, social marketing, establishment of demonstration gardens, are suggested.
- The development of vegetative propagation techniques and nursery procedures is central for fruit production for the wild and cultivated species alike. In this regard, the establishment of farmers' private and community nurseries and training would appear imperative. Besides, urgent wild fruits germplasm collection and the establishment of botanical gardens would be fundamental to the success of production and conservation.
- Apart from improving the existing material, the introduction of both wild and commercial economic fruit species and varieties would be commendable to diversify the resource

base and achieve a better economic return. It is also suggested that farmers be encouraged to establish orchards of priority wild fruit species.

- Technical backstopping and encouragement of fruit growers, at its minimum, to access quality planting material, water, market and training are vital.
- From the perspective of peoples' preferences and various other considerations, *Carissa* species*, D.abyssinica*, *D.mespiliformis, M. kummel, R. abyssinica, S.guineense, T.indica, X.americana* and *Z.spina-christi* among the wild species, and mango, guava, avocado, orange and papaya among domesticates appear priority species worth further in-depth investigation and promotion for domestication and /or wider utilization.

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8 Index of Tables

9 Table of Figures

10 Appendix

1. Sample household characteristics of the homegarden fruit study areas

Site	Sample size	Gender (%)		Age (years)			Number of years the family headed			Number of resident children			Education level			Training access (%)		Extension access (%)		Responsibility in the community (%)		Main job (%)		Off-farm job (%)	
	N	Male	Female	Lowest	highest	Mean	Lowest	highest	Mean	Lowest	highest	Mean	lowest	highest	Mean	Yes	No	Yes	No	Yes	No	Farming	other	Yes	No
Andassa	29	82.8	17.2	24.0	62.0	38±10.3	2	40	17±12.1	0	8	3.5±2.3	0	12	3.7±3.7	24.1	75.9	65.5	34.5	10.3	89.7	96.6	3.4	6.9	93.1
Robit	19	68.4	31.6	18.0	78.0	45.8±18.1	4	57	27.7±17.7	1	10	5.7±2.3	0	11	2.5±3.1	78.9	21.1	100.0	0.0	15.8	84.2	100.0	0.0	0.0	100.0
Wogelsa	19	84.2	15.8	19.0	75.0	42.4±12.2	1	40	18.9±10.7	0	10	4.7±2.4	0	8	2.4±3.1	42.1	57.9	100.0	0.0	21.1	78.9	100.0	0.0	10.5	89.5
Zeghe	20	80.0	20.0	28.0	70.0	47.25±11.8	9	55	26.6±13.2	1	11	5.3±2.6	0	11	3.4±4.4	10.0	90.0	20.0	80.0	10.0	90.0	100.0	0.0	20.0	80.0
Wangedam	25	88.0	12.0	18.0	68.0	40.8±12.9	2	49	25.7±12.3	0	8	4.4±2.4	0	11	3.1±3.2	40.0	60.0	100.0	0.0	48.0	52.0	100.0	0.0	28.0	72.0
Woinma	20	95.0	5.0	30.0	68.0	45.8±12.5	6	48	21.1±10.6	4	12	6.1±2.1	0	11	3.7±2.8	45.0	55.0	85.0	15.0	0.0	100.0	100.0	0.0	15.0	85.0
Arbayitu	15	100.0	0.0	30.0	64.0	48.3±8.9	8	48	27.3±10.4	1	10	5.5±2.5	1	12	3.3±3.3	13.3	86.7	100.0	0.0	20.0	80.0	100.0	0.0	33.3	66.7
All	147	85.0	15.0	18.0	78.0	43.4±12.9	1	57	23.0±13.1	0	12	4.9±2.5	0	12	3.2±3.4	36.1	63.9	80.3	19.7	18.4	81.6	99.3	0.7	15.6	84.4

2. List of plant species other than domesticated fruits in homegardens across sites

Scientific name	Family	Scientific name	Family
Multipurpose perrenial trees and shrub species		**Annual and biennial horticultural and field crops**	
Arundo donax L.	Graminae	*Allium cepa* L.	Alliaceae
Acacia abyssinica Hochst ex Benth.	Leguminosae	*Allium cepa* L.	Alliaceae
Acacia species	Leguminosae	*Allium sativum* L.	Alliaceae
Acokanthera schimperi (A.DC) Benth.	Apocynaceae	*Ananas comosus* (L) Merr.	Bromeliaceae
Albizia schimperiana Oliv.	Leguminosae	*Arachis hypogaea* L.	Papilionaceae
Aningeria altissima (A.chev)Aubrev &pelleg	Sapotaceae	*Beta vulgaris L.*	Chenopodeaceae
Bersama abyssinica Fresen.	Melianthaceae	*Beta vulgaris L.*	Chenopodeaceae
Buddleja polystachya Fersen.	Loganiaceae	*Brassica carinata* A. Br.	Brassicaceae
Casuarina equisetifolia L.	Casaurinaceae	*Brassica oleracea* L. Var Capitata	Brassicaceae
Celtis africana Burm.f.	Ulmaceae	*Capsicum* spp.	Solanaceae
Cordia africana Lam	Borginaceae	*Cucurbita moschata* Duch. Ex Poir.	Cucurbitaceae
Croton macrostachyus Del.	Euphorbiaceae	*Daucus carota* L.	Apiaceae
Diospyros abyssinica (Hiern) F. White	Ebenaceae	*Discorea abyssinica* Hochst. Ex Kunth	Dioscoriaceae
Diospyros mespiliformis Hochst.	Ebenaceae	*Helianthus annus* L.	Asteraceae
Dombeya torrida (J. F. Gmel.) Bamps	Sterculiaceae	*Hordeum vulgare* L.	Poaceae
Ensete ventricosum (Welw.) Cheeseman	Musaceae	*Ipomoea batatas* (L.) Lam.	Convolvulaceae
Ekebergia capensis Sparrm.	Meliaceae	*Lactuca sativa* L.	Asteraceae
Eucalyptus camaldulensis Dehnh.	Myrtaceae	*Lagenaria siceraria* (Mol) Stardl.	Cucurbitaceae
Eucalyptus globulus Labill.	Myrtaceae	*Lycopersicon esculentum* Mill.	Solanaceae
Euclea schimperi A.DC	ebenaceae	*Phaseolus vulgaris* L.	Fabaceae
Ficus sur Forssk	Moraceae	*Solanum tuberosum* L.	Solanaceae
Ficus sycomorus L.	Moraceae	*Zea mays* L.	Poaceae
Ficus thonningi Blume	Moraceae		
Ficus vallis - choudae Del.	Moraceae	**Cash crops**	
Ficus vasta Forssk.	Moraceae	*Catha edulis* (Vahl.)	Celastraceae
Gardenia ternifolia Schumach. & Thon	Rubiaceae	*Coffea arabica L.*	Rubiaceae
Girardinia bullosa (Steud.) Wedd.	Urticaceae	*Rhamnus prinoides* L`Herit.	Rhamnaceae
Gossypium hirsutum L.	Malvaceae	*Saccharum officianrum* L.	Poaceae
Grevillia robusta A.Cunn. Ex R.Br	Proteaceae	**Spice, aromatic, medicinal and other useful species**	
Maytenus obscura (A.Rich) Cuf.	Celastraceae	*Aframomum korarima* (Pereira) Engl.	Zingiberaceae
Melia azedarach L.	Meliaceae	*Artemisia absinthium* L.	Asteraceae
Millettia ferruginea (Hochst)Back.	Leguminosae	*Coriandrum sativum*	Apiaceae
Mimusops Kummel Bruce ex DC.	Sapotaceae	*Curcuma longa* L.	Zingiberaceae
Olea europaea L.	Oleaceae	*Cymbopogon ciratus* (DC ex Nees) Stapf	Graminae
Pittosporum spp		*Ocimum species*	Lamiaceae
Prunus africana (Hook.f)Kalkm	Rosaceae	*Otostegia integrifolia* Benth	Labiatae
Ricinus communis L.	Euphorbiaceae	*Ruta chalepensis* L.	Rutaceae
Rothmannia urcelliformis(Hiern)Robyns	Rubiaceae	*Trigonella foenum-graecum L.*	Fabaceae
Sesbania sesban (L.) Merr.	Leguminosae	*Zingiber officinale* L.	Zingiberaceae
Stereospermum kunthianum Cham.	Bignoniaceae	**Live Fence species**	
Syzygium guineense (Wild.) DC.	Myrtaceae	*Capparis* species	Capparidaceae
Urtica simensis Hochst. Ex Steud.	Urticaceae	*Cassia* species	Leguminosae
Vangueria volkensii K. Schum.	Rubiaceae	*Justicia schimperiana* (Hochst. Ex Nees)	Acanthaceae
Vepris dainelli (Pichi-Sermolli)Kokwaro	Rutaceae	**Parasite**	
Vernonia amygdalina Del.	Asteraceae	*Tapinanthus globiferus* (A.Rich.) Tieghem	Loranthaceae
Unidentified species ('*Kenedeba*', in Amharic)			

3. Area and production of fruits and other permanent crops in Amhara region

Crop type	Amhara region		West Gojjam zone	
	Area (hectares)	Production (quintal)	Area (hectares)	Production (quintal)
All	**21626.93**		**4480.1**	
Fruit crops	**1906.58**	**18359.8**	**171.61**	**881**
Avocados	*	*	*	*
Bananas	608.29	4289.99	47.24	253.82
Guavas	211.39	2271.34	9.38	*
Lemons	234.66	794.82	50.64	182.5
Mangoes	51.85	24.82	8.07	0.31
Oranges	488.16	8015.62	*	*
Papayas	262.15	2956.42	27.8	270.04
Pineapples	*	-	-	-
Stimulant crops	**18697.43**	**77186.16**	**4182.06**	**8730.07**
Chat	2008.2	9673.89	158.44	126.43
Coffee	6263.51	12772.06	1911.27	1383.31
Hops	10425.72	54740.21	2112.35	7220.32
Other permanent crops	**1022.93**	**9582.13**	**126.42**	**2998.62**
Enset	9.98	*	*	-
Sugar cane	1012.95	9576.98	126.02	2998.62

4. Fruit seedling distribution in Bahir Dar Zuria and Bure Districts (2002- 06)

Bahir Dar Zuria District						
Species	2001/02	2002/03	2003/04	2004/05	2005/06	Total
Mango	1436	1685	704	5046	965	9836
Avocado	1266	1508	2003	1883	2557	9217
Papaya	1747	2769	4714	3777	2958	15965
Peach	1623	1794	2810	1320	3019	10566
Lemon	0	0	320	1524	501	2345
Guava	884	743	35	1342	2075	5079
Banana	0	0	0	45	104	149
Citron	0	0	0	0	343	343
Custard Apple	0	0	0	0	59	59
Passion fruit	0	186	75	399	0	660
White Sapote	0	0	0	0	12	12
orange	350	0	0	0	0	350
Total	9300	8780	10757	15433	12691	54581
Bure District						
Mango		1429	8259	9622	7205	26515
Avocado		2818	9859	10293	10549	33519
Papaya		11229	17471	28897	14775	72372
Guava		1371	6654	5943	4901	18869
Banana		45	60	324	248	677
Orange		75	108	31	16	230
Mandarin		0	17	0	0	17
Lemon		0	0	2	0	2
Total		16967	42428	55112	37694	152201

***Source*: Bahir Dar and Bure District Agriculture and Rural Development offices**

11 Abbreviations

ADA	Amhara Development Association
ASL	Above Sea Level
BC	Before Christ
BOA	Bureau of Agriculture
BoARD	Bureau of Agriculture and Rural Development
BoFED	Bureau of Finance and Economic Development
C°	Degree Celsius
CEC	Cation Exchange Capacity
CPAR	Canadian Physicians for Aid and Relief
CACC	Central Agricultural Census Commission
CSA	Central Statistical Agency
DA	Development Agent
DARD	Department of Agriculture and Rural Development
ETB	Ethiopian Birr
ETC	Ethiopian Cents
FAO	Food and Agriculture Organization
FGD	Focus Group Discussion
FTC	Farmers' Training Center
GLM	General Linear Modeling
ha	Hectare
IBCR	Institute of Biodiversity Research and Conservation
ICRAF	International Center for Research in Agroforestry
IPGRI	International Plant Genetic Resources Institute
Kcal	Kilo calorie
kg	Kilogram
km	Kilometer
mm	Millimeter
n.a.	Not available
n.d.	Not dated
NGO	Non - governmental Organization
NMDS	Non - metric Dimensional Scaling
MOA	Ministry of Agriculture
PA	Peasant Association
PCA	Principal Component Analysis
PcoA	Principal Coordinate Analysis
SD	Standard Deviation
SE	Standard Error
SIM	Serving in Mission
SMNP	Semen Mountains National Park
SOS	Save Our Soul
USAID	United States Agency for International Development
WHO	World Health Organization

12 Curriculum Vitae

Personal data

Name	Fentahun Mengistu Tiruneh
Date of Birth	02.11.1967
Place of Birth	Dangilla, Gojjam
Country	Ethiopia
Nationality	Ethiopian
Marital status	Married
University	BOKU, Vienna, Austria

Education	October 2005 - September 2008: PhD at Boku University of Natural Resources and Applied Life Sciences, Vienna, Austria.
	September 1997 - March 2000: Master of Science (M.sc) in Horticulture at Indian Agricultural Research Institute, India.
	September 1985 - July 1989: Bachelor of Science (B.Sc) at Alemaya University of Agriculture, Ethiopia.
Short - term training	January - July 2003: Diploma upon participation in “Professional training on inter - disciplinary team research in agriculture”. International Centre for Development - oriented Research in Agriculture (ICRA), Wageningen, The Netherlands.
Professional experience	September 1989 - November 1994: Junior researcher in Crop protection at the Ethiopian Science and Technology Commission, Plant Protection Research Center, Ambo.
	Since 1995 at Adet Agricultural Research Center, Ethiopia with the following research positions and capacities:
	December 1995 - June 1997: Junior Researcher in Entomology / Pathology
	Since July 1997: Assistant Researcher III, Associate Researcher I and Researcher I in Horticultural crops research
	Alongside of the research positions, Director of Adet Agricultural Research Centre from November 1996 - July 1997 and September 1999 - December 2002.

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