**Zentrum für Entwicklungsforschung**

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# The role of local agroforestry practices for enhancing food and nutrition security of smallholding farming households:

## The case of Yayu area, south-western Ethiopia

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Von

**Omarsherif Mohammed Jemal**

aus

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Referent: Prof.  Dr. Meine van Noordwijk

Korreferent: Prof. Dr. Christian Borgemeister

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## ABSTRACT

When agriculture becomes focused on globally traded commodities, local nutrition may be at risk. The study tested this hypothesis in the coffee landscape of Yayu, south-west Ethiopia, by investigating the role of local agroforestry practices (AFP) toward food and nutrition security (FNS).

Through survey data collected from 300 smallholding farming households, three forms of AFP were identified: homegarden (HG), multistorey-coffee-system (MCS) and multipurpose-trees-on-farmlands (MTF). Multipurpose-trees-on-farmlands are mainly for food production, MCS for income generation and HG for both. Across all three practices, 127 useful plant species were identified, with 80 edible species of which 55 were primarily cultivated for the household food supply.

The food and nutrition surveys reveal that the farming communities of Yayu are hunger free. However, about 20% of the households face moderate to severe food insecurity through limited access to food, regardless of seasons. The prevalence of wasting, underweight and stunting indicate certain forms of hidden hunger, such as iron deficiency.

Coupling AFP and FNS data reveals that household access to all three AFP was the primary basis of household's food security. A search for specific options to address the detected seasonal and nutritional gaps identified plant resources both within and around the AFP in Yayu.

Out of 25 potentially edible species, 12 were confirmed to be available during the shortage season. Nutritional assessment of these species revealed species with good potential to enhance the supply of calories, protein and vitamin A. The maintenance of landscape mosaic diversity is key to food security in this coffee landscape.

# Die rolle der lokalen agroforstlichen Praxis zur Verbesserung der Nahrungs- und Ernährungssicherheit von kleinbäuerlichen Haushalten: Der Fall der Yayu-Region im südwesten Äthiopiens

## KURZFASSUNG

Die vorliegende Arbeit widmet sich der Hypothese, dass die Spezialisierung der landwirtschaftlichen Produktion auf weltweit handelbare Güter zu einem Risiko für die lokale Nahrungsmittelsicherheit werden kann. Dazu wurden Praktiken der lokalen Agroforstwirtschaft (AFP) in Yayu im südwestlichen Äthiopien untersucht und ihr Verhältnis zur Nahrungsmittelsicherheit (FNS).

Auf Grundlage einer empirischen Datenerhebung mit 300 Haushalten wurden drei unterschiedliche AFPs identifiziert: Heimgärtnerei (HG), mehrstöckige Kaffee-Systeme (MCS) und Mehrzweck-Forstsysteme auf bäuerlichem Land (MTF). MTFs dienen vorwiegend der Nahrungsmittelproduktion, während MCSs zur Generierung von Einkommen dienen und HGs eine Mischform der beiden Ziele darstellen. Insgesamt wurden in den drei Systemen 127 Pflanzenarten identifiziert, wovon 80 essbar sind und 55 primär für die Nahrungsmittelproduktion kultiviert werden.

Die Ergebnisse zu Nahrungsmittelkonsum und Nahrungsmittelsicherheit zeigen, dass die lokalen Gemeinschaften insgesamt als hungerfrei zu bezeichnen sind. Nichtsdestotrotz sind 20% der Haushalte von moderater bis starker Nahrungsmittelunsicherheit betroffen, wegen defizitären Zugang zu Nahrungsmitteln, unabhängig von der Jahreszeit. Das Auftreten von Schwindsucht, Untergewicht und Wachstumsdefiziten deutet auf das Phänomen des versteckten Hungers hin, der beispielsweise durch Eisenmangel charakterisiert sein könnte.

Die gemeinsame Betrachtung von AFP und FNS deutet darauf hin, dass der Zugang der Haushalte zu allen drei Praktiken der AFP die primäre Basis für Nahrungsmittelsicherheit darstellt. Einige Pflanzen innerhalb der AFPs in Yayu bieten konkrete Möglichkeiten, um die saisonalen und nahrungsmittelbedingten Defizite zu mindern.

Von 25 potentiell essbaren Pflanzenarten können 12 auch in der Defizitsaison angebaut werden. Untersuchung zu den Nahrungsmitteleigenschaften eben dieser Arten zeigen gutes Potential, um die Bereitstellung von Kalorien, Proteinen und Vitamin A zu erhöhen. Der Erhalt der Landschaftstruktur (kleinbäuerliche Mosaike) ist dabei eine Grundvoraussetzung, um die Nahrungsmittelsicherheit in diesen Kaffee-Kulturlandschaften zu garantieren.

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## ACRONYMS

| | |
|---|---|
| ADLI | Agricultural Development Led Industrialization |
| AFP | Agroforestry Practices |
| AOAC | Association of Official Analytical Chemists |
| BMI | Body Mass Index |
| BOFED | Bureau of Finance, Economy and Development |
| CFS | Committee on World Food Security |
| CRGE | Climate-Resilient Green Economy |
| CSA | Central Statistics Agency |
| CSI | Coping Strategy Index |
| DFID | Department for International Development |
| EP | Edible Portion |
| EPHI | Ethiopian Public Health Institute |
| FANTA | Food and Nutrition Technical Assistance |
| FAO | Food and Agriculture Organization of the United Nations |
| FCS | Food Consumption Score |
| FDRE | Federal Democratic Republic of Ethiopia |
| FEWS NET | Famine Early Warning Systems Network |
| FHI | Family Health International |
| FNS | Food and Nutrition Security |
| HAZ | Height-for-age z-score |
| HDDS | Household Dietary Diversity Score |
| HFIAS | Household Food Insecurity Access Scale |
| HG | Homegarden |
| HH | household |
| HHS | Household Hunger Scale |
| ICRAF | World Agroforestry Centre (International Council for Research in Agroforestry) |
| IDDS | Individual Dietary Diversity |
| INRES | Institute für Nutzpflanzenwissenschaften und Ressourcenschutz |

| | |
|---|---|
| m.a.s.l. | Meters above sea level |
| MCS | Multistorey Coffee System |
| MDD | Minimum Dietary Diversity |
| MDD-W | Minimum Dietary Diversity Score for Women |
| MGRS | Multicentre Growth Reference Study |
| MoFED | Ministry of Finance and Economic Development |
| MTF | Multipurpose Trees on Farmland |
| NBF | Non-breast Feeding |
| PRFP | Person Responsible for Food Preparation |
| PSNP | Productive Safety Net Program |
| rCSI | Reduced Coping Strategy Index |
| WAZ | Weight-for-age z-score |
| WFP | World Food Programme of the of the United Nations |
| WFP-VAM | World Food Programme-Vulnerability Analysis and Mapping |
| WHO | World Health Organization of the United Nations |
| WHZ | Weight-for-height z-score |
| WRA | Women of reproductive age |
| UN-DESA-PD | United Nations-Department of Economic and Social Affairs-Population Division |
| UNESCO | United Nations Educational, Scientific and Cultural Organization |
| UV-Vis | Ultraviolet-visible |

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# 1 GENERAL INTRODUCTION

## 1.1 Background

Food and nutrition security still is a major global challenge. Despite the remarkable reduction in the proportion of undernourished people, i.e. 7.7% since the beginning of the 1990s, there are still about 800 million people suffering from undernourishment (FAO et al. 2015). This situation is worsening through the annual global population growth of 1.18%, and an expected increase of 2.3 billion people by 2050, which will increase the global food demand by about 70% ( FAO 2009a; UN-DESA-PD 2015).

Food and nutrition insecurity is not globally equally distributed. Both population growth and the prevailing undernourishment are mainly localized in Asia (65.6%) and Africa (29.8%) (FAO et al. 2015). Moreover, these regions are heavily hit by other factors that trigger undernourishment, such as social-economic problems, conflicts and natural calamities (Endalew et al. 2015). For instance, the demographic pressure in south-east Asia, conflicts in central Africa and Middle East countries and climatic disasters in eastern Africa have contributed to the overall undernourishment of these regions (FAO et al. 2015). Also, the globalization of food markets made import-dependent countries, especially in Sub-Saharan Africa, even more vulnerable to global price fluctuations and the consequent food availability as in 2007-2008 (Stewart et al. 2008; von Braun et al. 2008; Wiggins et al. 2010). Another challenge is the increasing cultivation of non-food cash crops and the use of food crops as a biofuel feedstock that have created competition for means of production and added to the instability of food markets (Afiff 2013).

Thus, a mere increase in global food production may not secure global food security (Pieters et al. 2013), and exploring the local production of food as an option to achieve food and nutrition security (FNS) in affected agrarian countries is suggested (CFS 2015). However, producing food locally has its own challenges, and is also influenced by the rapid population growth in such areas and the globalization of the markets for food and non-food biomass products. For instance, the demand for cash to cover the production costs of commercial and/or non-food agricultural products creates competition for the basic means of production such as land, water, and labor (Brüntrup and Herrmann 2010; Kuhn and Endeshaw, 2015; Virchow et al. 2016). Furthermore, the international demand for agricultural non-food products is strongly influencing the type of crops produced by small-scale farming households (Keyzer et al. 2005; Dose 2007; Kuhn and Endeshaw 2015; Virchow et al. 2016). This competition among crops may not only cause a decline in the amount of food produced but also deepen the fragmentation and marginalization of land due to over-exploitation, which would contribute to food insecurity and poverty.

In contrast, incorporating cash crops would positively contribute to FNS through enhancing the income security of the households, which would ultimately improve the access to the food available in the local market. Household income security is a key factor in rural smallholding households especially in areas dominated by cash crops. Such areas usually outsource storable cereal staples and pluses to other areas and focus only on cultivation of these cash crops and non-storable food crops, and depend on the income generated by selling cash crops for buying their main staple food (van Noordwijk et al. 2014).

Beyond the provision of sufficient food, adequate quality food to guarantee the people's optimal development and performance is necessary. A lack of essential micronutrients in the daily food intake of individuals is another form of food insecurity challenging most developing countries. This state, often termed as 'hidden hunger', may occur even when food with sufficient calories is consumed, and may only be detectable at the clinical level (FAO et al. 2012; Biesalski 2013). At an early age, hidden hunger leads to stunting and anemia, harms cognitive development irreversibly, and leads to poor intellectual, physical and economic performance in adulthood (Arcand 2001; Stein and Qaim 2007). Currently, combating hidden hunger has been endorsed by national and global efforts that address the challenge of food insecurity (FAO et al. 2012; CFS 2015).

In this complex scheme, the demand for smart farming systems that can address FNS and also satisfy other material and cash needs of the population with minimal impact on the environment is still an issue. Among a few options, agroforestry is currently widely promoted and implemented as a viable land use capable of addressing the multifaceted problem of food security of small-scale farming households, especially in impoverished agrarian countries (Frison et al. 2011; Bishaw et al. 2013; Jamnadass et al. 2013; Mbow et al. 2014; Dawson et al. 2014). However, in spite of the recognized potential of agroforestry systems to provide a variety of goods and services, the degree of their impact is known to be site specific (Mbow et al. 2014). Therefore, the inherent variability among agroforestry systems and practices requires, ahead of their implementation, the understanding of the conditions where it may be implemented and the trade-offs across the achievement of its intended goals (Mbow et al. 2014).

## 1.2 Problem statement

Food and nutrition security is still a major issue in Ethiopia. Two decades ago, the country was directly associated with famine by the international community (von Braun and Olofinbiyi 2007; Block and Webb 2001). During the 1980s, around 52% of the Ethiopian population consumed less than the recommended daily food intake of 2,100 kcal (Clay et al. 1999). In the 1990s, more than 50% of Ethiopia’s farming households did not produce enough to satisfy their basic needs and lacked the means to purchase food (Tesfaye and Debebe 1995). Presently, regardless of the significant risk reduction in famine occurrence and that the average daily calorie intake has reached 2,192 kcal (FAO 2015), the country is still home to more than 30 million undernourished people, the fourth largest number in the world (Endalew et al. 2015; FAO et al. 2015).

The country is mainly an agrarian country, where the farming methods are characterized as traditional with a low use of modern technology and inputs, highly dependent on rainfall, and oriented to smallholding subsistence (Mengistu et al, 2009). For instance, farmers’ average application of inorganic fertilizers in 1999/2000 was only about 35 kg/ha (Kuma 2002), and in 2014 only 21.8 kg/ha (WB 2017). The irrigated land accounts for less than 2% of the total cultivated land of the country, and the total cereal crop yields ranged from 1.2 to 2.34 tons/ha during the early 2000’s (Degfe and Nega 2000; Taffesse et al. 2011).  As a result, productivity is among the lowest in the world and unable to adequately feed the country’s population (Devereux 2000; MoFED 2006; FAO 2015).

Besides the poor performance of the agriculture sector, the food insecurity of Ethiopia is linked to the rapid population growth, which has led to a high demand for both food and agricultural non-food products (food, fuel, fodder, and fiber), and thus also for the production means land, water, and capital. Consequently, the proportion of arable land is decreasing both in size and productivity, while land-use conversion is increasing. If population growth and investments continue at the current levels, an area of 9 million ha of forest might be deforested between 2010 and 2030 for agricultural use (Bishaw et al. 2013).

Also, the availability of domestic fuel in rural areas is continually decreasing leaving the households no option but to use crop residues and manure as fuel. This leads to further deforestation causing a rapid degradation of the farmlands. According to Bishaw et al. (2013), from 2010 to 2030, the annual fuelwood consumption of Ethiopia will increase by 65% requiring more than 22 million tons of woody biomass, which in turn will further aggravate forest degradation. These factors all have a direct impact on food security by causing land/soil degradation due to over-exploitation and deforestation. Moreover, due to the shortage of fuel for cooking, the productivity of the farming households is reduced as there is competition between the labor required and the time for fetching fuelwood, which poses a risk to the health of the household members.

To address these problems, during the last two decades the Ethiopian government has designed and is implementing different policies and strategies focusing on encouraging agriculture growth, overcoming poverty, and enhancing food security (FDRE 1996; FDRE 2004). The Agricultural Development Led Industrialization (ADLI), Productive Safety Net Program (PSNP) and Climate-Resilient Green Economy (CRGE), are the most prominent programs (Guillozet 2011; Gilligan et al. 2009; Bishaw et al. 2013). These all include a focus on fostering forestry and agroforestry, and on improving agricultural productivity and energy efficiency (Guillozet 2011; Gilligan et al. 2009; Bishaw et al. 2013). This indicates the growing interest in agroforestry for solving the multifaceted problems in the country.

In spite of the recognized potential of agroforestry for fostering economic development and food security, its inherent variation in type and purpose have limited its universal application. Mbow et al. (2014) stated that the success of agroforestry practices is strictly site specific. Therefore, the current state of knowledge offers very little guidance on where a system can work, for whom and under what circumstances. This implies that the success of agroforestry as a tool for addressing poverty, food insecurity, and environmental degradation is highly dependent on the effectiveness of prescribing the correct type of agroforestry based on the type of problem and the site conditions.

The diverse agro-climatic conditions and multi-ethnic composition of Ethiopia have contributed to the evolvement of different forms agroforestry, e.g. the Faidherbia albeda-based parklands agroforestry predominately observed in the eastern highlands and rift valley area (Poschen 1986; Hoekstra et. al. 1990; Abebe 2000; Bishaw and Abdelkadir 2003). Similarly, the enset-coffee-based homegardens known as *guwaro* are widely observed in the southern and south-western areas of the country (Asfaw 2002; Tesfaye et al. 2010; Sahilu 2017; Melissa et al. 2017a). The coffee-based agroforestry practices of the south-western regions are the dominant farming system there (Martins 2008; Gole et al. 2009; Kebebew et al. 2011; Gole 2015). The potential of these agroforestry systems widens the list of choices for the government or any other practitioner to address the food insecurity of the smallholding farming households in the country. However, the role of most of these traditional agroforestry systems as food security contributors in Ethiopia has not been studied.

The traditional agroforestry systems in Yayu in south-western Ethiopia are among the most widespread and best performing agroforestry practices, and support the livelihoods of the local population while maintaining environmental integrity (Assesfa 2010; Senbeta et al. 2013). A number of studies on the area exists, mainly on ecological, diversity and conservation aspects. However, little attention has been given to the role of the systems with respect to food and nutrition provision. Hence, to fill this scientific knowledge gap, this study was designed to determine the role of local agroforestry practices in the food and nutrition security of smallholding farming households in Yayu, south-western Ethiopia.

Empirical data on the contribution of agroforestry practices to the food and nutrition security of smallholding farming households hardly exists, making it difficult to make sound predictions for the affected areas. Therefore, the present study aims to contribute towards filling the scientific knowledge gap regarding local agroforestry practices and their roles in fostering food and nutrition security by examining the case of Yayu.

## 1.3 Objectives

The overall objective of this study was to determine the role and potential of the local agroforestry practices (AFP) toward the food and nutrition security (FNS) of smallholding farming households based on a case study involving the communities of Yayu.

The specific objectives were:

- To identify the major forms of AFP of smallholding farming households.
- To characterize the major AFP of smallholding farming households emphasizing their potential for food and nutrition security.
- To determine the food security status, dietary habits and nutritional status of smallholding farming households via proxy tools.
- To investigate the existing variation in food security status, dietary habits, and nutritional status of smallholding farming households across seasons and in relation to the household attributes.
- To determine the relationship among the AFP and FNS attributes of the smallholding farming households.
- To assess the additional potential of the native plant species existing in the surrounding areas for enhancing FNS by assessing their nutrient contents.

## 1.4 Conceptual/operational framework

The objectives of the study were operationalized systematically (Figure 1-1) to capture the role of local AFP to enhance FNS of the smallholding farming households of Yayu. First, identification and characterization of the local AFP were done to capture the supply side of the food/environment system of the area. Then the food and nutritional status of the people was assessed to understand how the supply side is efficiently utilized by the households.

The analysis of the performance of AFP for FNS was done by assessing the relationships among the attributes of each parameter. Finally, the untapped potential of AFP was assessed with respect to filling the detected nutritional gaps (Figure 1-1).

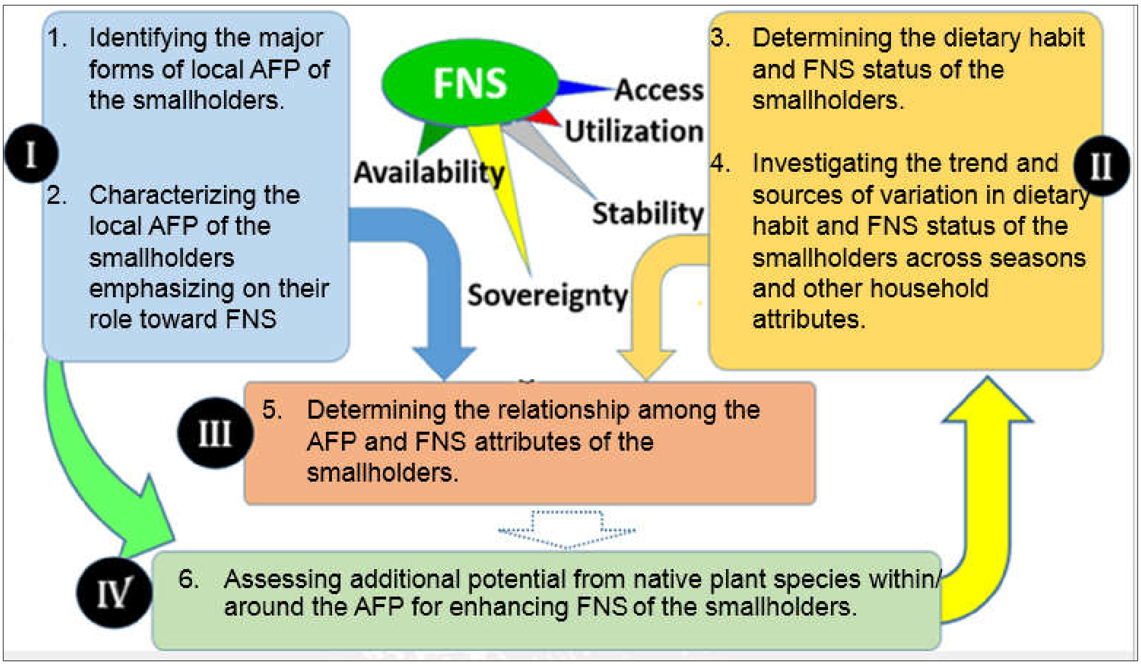


Figure 1-1 Conceptual/ operational framework of the study.

## 1.5 Structure of the dissertation

This dissertation is organized into eight chapters.

Chapter 1 focuses on the background and the rationale of the study and presents the objectives and the structure of the work.

Chapter 2 covers the state of knowledge about the main cross-cutting topics of the study, e.g. food and nutrition security, agroforestry and their nexus.

Chapter 3 provides general information about the study area and the sampling procedure.

Chapter 4 reveals the major local agroforestry practices carried out by smallholding farming households, and details the respective characteristics concerning their contribution to the food and nutrition of the households.

Chapter 5 presents the findings on food security, dietary adequacy, and nutritional status of smallholding farming households in Yayu.

Chapter 6 details the observed correlations between the identified AFP and the FNS attributes of the smallholding farming households in Yayu.

Chapter 7 deals with the nutrient content of selected species growing in the identified AFP and their contribution to FNS.

Chapter 8 provides a general synthesis and the conclusions of the study.

## 1.6 Limitation of the study

Ph.D. studies are generally characterized by a certain time limit, so it is a challenge to study such a complex issue as agroforestry and FNS with a high level of precision. To overcome this problem, different measures were taken to prevent jeopardizing the reliability and relevance of the findings of the study. Nonetheless, shortcomings exist. Therefore, for the future utilization of the study findings, it is important to indicate the limitations.

During characterization of the AFP, only useful species were assessed. Plot size to assess the inventory of the plant species was not standardized, and the pre-defined household plot was used. Thus, this study does not show the total floristic diversity of the area.

The characterization of the AFP focuses only on the plant components and excludes forest fauna, and also poultry, cows, sheep, etc. However, these components were indirectly considered when the utilities of the plant species were assessed, e.g. fodder, forage, honey.

For determination of the nutritional status of a household, no direct blood analyses were performed, but proxy tools such as dietary recall and anthropometric tools were applied. In addition, except for the type and frequency of the household diets, a detailed analysis of quantity and nutritional value of the diets was not performed. The analysis of the nutritional value of potentially edible species focused only on those species with foodstuff harvestable during the shortage season.

# 2 STATE OF KNOWLEDGE ON FOOD AND NUTRITION SECURITY AND AGROFORESTRY

## 2.1 Food and nutrition security

### 2.1.1 Evolution of the concept

The germinal idea of food and nutrition security dates from 1943 when the emerging United Nations underlined the importance of *"(a) secure, adequate and suitable supply of food for everyone*" (UN Conference on Food and Agriculture 1943), and came up with the term 'food security', which since then has been subject to upgrading and refinements as the global situation and understandings changed (Maxwell and Smith 1992).

The first official definition of food security was proposed at the 1974 World Food Conference, which was held in response to the drop in the global food stock that caused a substantial food price increase and a decrease in food availability in many countries. The concept of 'food assurance' was proposed and referred to as "*(the) availability at all times of adequate world food supplies of basic foodstuffs to sustain a steady expansion of food consumption and to offset fluctuations in production and prices."* (United Nations 1975). Previous concepts had emphasized the redistribution of 'surplus' production in shortage areas, while 'food assurance' embodied a fundamental paradigm shift by rather focusing on food scarcity.

In subsequent years, despite the boom in global food production achieved through the green revolution, the problems of famine and food shortage were not solved in many countries, as some social groups could not afford the access to the food available on the market. This became the concept of entitlement (Sen 1981), later used to state that '' (…) *the adequacy of food supply would not be sufficient to pledge food security, except the deprived and susceptible people had the physical and economic access to that food*'' (CFS 2012). In addition, the World Bank added a temporal dimension by classifying food insecurity situations as chronic and associated with poverty, which implies long-term and persistence, and transitory when referring to short-term shocks and shortages of food. Hence, the definition of food security has been modified as "*(the) access of all people at all times to enough food for an active, healthy life*" (World Bank 1986).

In 1996 during the World Food Summit, 'nutrition' was incorporated in the definition of food security, and the four dimensions of FNS implicitly involved: "*Food security is met when all people, at all times, have physical and economic access to sufficient, safe, and nutritious food to meet their dietary needs and food preferences for an active and healthy life*" (FAO 1996). In 2002, the 'social' component was added, i.e. that people "(…) *have physical, social and economic access* (…)" (FAO 2002). At the 2009 World Summit on Food Security, the relevance of the four dimensions (since then called pillars) was explicitly defined: "*(the) four pillars of food security are availability, access, utilization, and stability*" (FAO 2009b).

In spite of the inclusive definition of food security, currently many institutions tend to use the term food and nutrition security to emphasize the greater importance of the utilization pillar compared to the pillars food availability, access and stability (CFS 2012; Pangaribowo et al. 2013). In this study, both terms are used interchangeably.

### 2.1.2 Pillars of food and nutrition security

The switch from 'dimensions' to 'pillars' was questioned by suggesting a separation between the food security components instead of their interrelatedness and interdependence (Berry et al. 2015). However, even if they are arranged hierarchically, their interconnectedness is plausible as shown by Weingärtner (2004), which was prior to the explicit definition of FAO in 2009 (2009b). During the last two decades, a new dimension, i.e. the sovereignty pillar, has been added by different institutions (Figure 2-1).

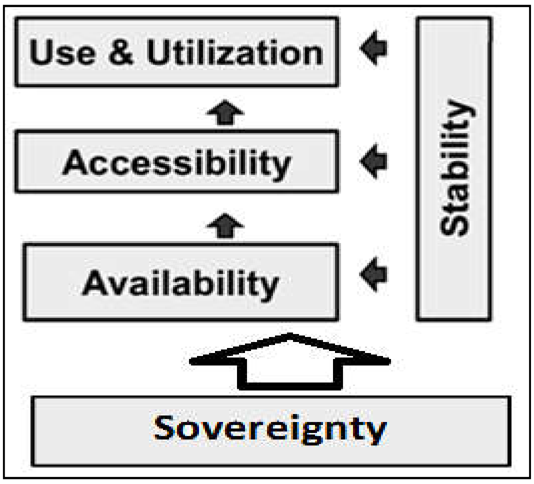


Figure 2-1. Interconnectedness among the pillars of food and nutrition security (adapted from Weingärtner 2004) .

The first pillar of food security is food availability. It represents *“the existence and supply of sufficient amount of food ready for consumption for all individuals in the household, country and region, via production, distribution, exchange and/or aid*’’ (FAO 2006). At the household level, food availability refers to an adequate amount of food for all household members, either through self-production or by purchase. For example, in the Tigray region of Ethiopia, the average household production covers about 38% of the annual food demand (BoFED 2004), so food availability can only be met via purchasing, or aid, etc. At a national scale, availability refers to the country’s capability to offer an adequate amount of food either from inland production or imports. Hence, a country is considered food secure if it has a sufficient food stock and/or currency reserves to meet the gross national food demand in times of crop failure, global food price spikes or both (Diaz-Bonilla et al. 2006; Ecker and Breisinger 2012). In the long term, this pillar should be achieved by taking measures to improve the productivity of agriculture, access to markets, efficient food distribution, etc.

Although food availability may appear dependent on the supply side, this may not be always the case. The existence of sufficient food in a given household, locality or even a country does not guarantee that all persons have equal access to food. At the local level, food may be available in the market, but some households may not have the economic or social power to buy it. Similarly, at the national level, some regions might be isolated, physically, economically, socially or politically and therefore less favored to access the national food stock (FAO 2006). This implies that availability of food may not be enough to bridge food security unless the food is equally accessible for all member of the society.

This leads to the second pillar of food security: access. This pillar refers to the capabilities of regions, localities, households and/or individuals within those households to acquire sufficient access to resources and rights to obtain a sufficient amount and quality of food (Riely et al. 1999; Gross et al. 2000; Rivera and Qamar 2003). At the household level, it refers to warranting the access of all members of the household to a sufficient amount of food according to their physiological and psychological needs and preferences (Weingärtner 2004; FAO 2006). It matters, as social, economic or cultural factors such as favoritism, gender bias, and/or educational limitation influence the distribution of food among household members (Weingärtner 2004; Pieters et al. 2013). For instance, in some parts of Ethiopia, females, mainly mothers, smaller food amounts, fewer number of meal and/or inferior quality food than male members of the same household (Mengesha and Ayele 2015).

Drivers of food access are household resources, food prices, food preferences, and socio-political factors such as discrimination and gender inequality (Pieters et al. 2013). Alternatively, attempts to attain food access are made at broader scales by developing infrastructure like roads and communication, negotiations with controlling groups, improving food markets chains via measures like subsidies, taxes and tariff exemption, enhancing local production, and enhancing farm and off-farm income (Clay 2002; Weingärtner 2004; Diaz-Bonilla et al. 2006; Ecker and Breisinger 2012; Hoddinott 2012).

The third pillar is utilization. It denotes the ability of an individual to use food in a way that all physiological requirements are satisfied. Besides the quality of the food, it defines the importance of non-food aspects, such as availability of clean water and cooking fuel, hygiene and sanitation. These are the underpinning elements of this pillar, i.e., diversity diet, proper preparation and handling of food, and absorption efficiency (Weingärtner 2004; FAO 2008; Pangaribowo et al. 2013; Pieters et al. 2013).

(i) **Diet diversity**. This refers to the content of the food of the optimum amount of calories and nutrients required by each member of a household. The household's staple crops may offer sufficient energy, but the food may not contain optimum amounts of essential macro- and micronutrients, thus making the household members prone to malnutrition. Currently, this is the situation for more than 2 billion people in the world (FAO et al. 2012). Alternatives at the household level are economic, educational, cultural and behavioral measures to promote the inclusion of animal products, fruits and vegetables in home diets. It has been proven that wealthier and better-educated people consume more diversified diets (Hatløy et al. 2000; Ruel 2002). At a broader scale, the efforts to provide more nutritious food and scarce nutrients towards increasing a more diversified diet have been tackled applying different approaches, e.g. through government interventions such as fortification, biofortification and/or fertilization of staple crops or through the introduction and promotion of fruit and vegetable species (Ruel 2002; Pieters et al. 2013).

(ii) **Proper preparation**. The presence of nutritious food does not guarantee FNS. Non-food inputs like clean water and energy are needed to prepare, consume and assimilate food. At the household level, the access to sufficient clean water and energy as well as their proper use and handling are crucial factors to secure a safer, more palatable and more energy-efficient consumption of food. At the national level, the physical and economic potential of a country and the managerial capabilities of its government are the key factors for the supply of clean water and energy to households, which is an acute problem in the case of the urban poor and rural communities (FAO 2008; Pangaribowo et al. 2013).

(iii) **Absorption efficiency**. Also known as ’nutrient utilization’, absorption efficiency is about a person’s physiological efficiency to absorb the consumed food, and it is therefore well correlated with the health status of the individual, and if deficient can impair the person’s ability to benefit from the food (Weingärtner 2004). At the household level, absorption efficiency depends on the economic, educational and physical characteristics of households with respect to caring for the health of the family members. At larger scales, governments can indirectly influence this factor by enlarging and providing efficient waste management schemes, health care facilities, or national vaccination systems.

The fourth pillar, stability, defines the lastingness of the three other dimensions for long periods of time (FAO, 2009b). Events like food price hikes, floods, droughts, pest outbreaks, etc., can cause economic or environmental shocks that may lead to a food-secure household becoming insecure. Stability comprises two general attributes, namely carrying capacity, i.e. the tolerance level of the subject against harming events, and resilience, i.e. the capability and time required to recover from that event (Pieters et al. 2013). Accumulation of assets prior to the occurrence of shocks, such as storing food and saving cash, may significantly enhance the carrying capacity and resilience of households during calamities. This indicates the importance of a precautionary behavior, which is even more important if harming events are of a cyclic nature. At the national level, the amount of food or currency reserves determine the level of carrying capacity and resilience of a given country. In addition, preparedness to confront shocks, such as early warning systems, risk prevention education, risk mitigation, and damage minimization mechanisms, can also contribute to stabilizing the food supply (Løvendal and Knowles 2005; van't Wout et al. 2014).

In 1996, at the same World Food summit where food security was defined, the International Peasant’s Movement La Via Campesina came up with a new dimension of food security, i.e. ‘‘food sovereignty’’, a fifth pillar for food security (Lee, 2007, Patel 2012). They defined food sovereignty as “… *the right of each nation to maintain and develop its own capacity to produce its basic foods respecting cultural and productive diversity. We have the right to produce our own food in our own territory. Food sovereignty is a precondition to genuine food security*” (Via Campesina, 1996). Unlike other pillars that focus on the ultimate goal of food security, ‘food sovereignty’ focuses on the way to achieve food security. At the national level, food sovereignty refers to the freedom of a country to define its own food system model (Dupraz and Postolle 2013). At the household level, it refers the capacity or potential of a household to decide what food to grow, buy and/or consume (AltierI 2009; Wilson 2015: Ngcoya and Kumarakulasingam 2017).

### 2.1.3 Temporal dimension of food and nutrition (in)security

Based on its temporal nature, food insecurity can be grouped into three forms, i.e. transitory, chronic and seasonal/cyclic. Transitory food insecurity is a temporary shortage of food or access to food (Maxwell and Smith 1992). According to the World Bank (1986), it occurs mainly due to a year-to-year or sudden fall in domestic food production, to the international price for food and/or other agricultural commodities, and/or to hard currency balance. In general, transitory food insecurity exhibits an unpredictable nature, so that it requires building up different preventing strategies, such as warning systems and safety net programs, and stacking sufficiently large reserves of food and hard currency.

In contrast, chronic food insecurity refers to a long-term or relentless shortage of food. According to DFID (Department for International Development), chronic, food insecurity occurs when people are unable to meet their minimum food requirements over a sustained period of time (Wiggins et al. 2004). This mostly occurs in the case of persistent poverty and shows a long-term structural shortfall in food production and a weak economic power (Devereux 2006). As chronic food insecurity is predictable, it requires long-term developmental and political measures, which relate to the improvement of the overall wellbeing of the society.

The third temporal form of food insecurity is seasonal or cyclic food insecurity. This type of food insecurity occurs whenever there is a cyclic shortage of either available or accessible food. It might be linked with seasonal cropping patterns, selling-time pattern of products, work opportunities (labor demand) and/or prevalence of diseases (Haile 2005; Sarker 2016; Sassi 2017). For example, food shortages may occur in the pre-harvest period, when crop stocks are depleted either from the house or market or both. In agrarian communities ‘shortage periods’ and ’surplus periods’ of food availability are common depending on the harvesting and or selling seasons of the harvests. According to Devereux (2006), seasonal food security shares the character of both chronic and transitory food insecurity. As its duration is short, (seasonal) it can be regarded as transitory, but due to its predictable and recurrent nature, institutions consider it as chronic.

### 2.1.4 Indicators of food and nutrition (in)security

A food and nutrition (in)security status can generally be measured at the macro and micro level (Bickel et al. 2000; Pérez-Escamilla and Segall-Corrêa 2008; Walton 2012). The macro level includes national, regional and global scale of food and nutrition insecurity prevalence; these are not the focus of the present study. The micro level includes individual and household level food (in)security. As this study focuses on the household food and nutrition security status, which is the result of the cumulative status of all individuals in the household, the currently available indicators to assess both are reviewed below.

As a multidimensional and a complex concept, the comprehensive aspects of FSN cannot be assessed by any single indicator. Instead, multiple types of indicators of different scopes of measurement are used simultaneously depending on the purpose of the assessment (Bickel et al. 2000; Pérez-Escamilla and Segall-Corrêa 2008). Presently, various indicators to assess individual and household food security exist, and include adequacy of energy intake, nutrient intake adequacy, physical performance, malnutrition, household expenditure, poverty- or income-related, etc. (Maxwell et al. 1999; Bickel 2000; Pérez-Escamilla and Segall-Corrêa 2008; Walton 2012). The present study systematically reviewed the available approaches and indicators, and selected those related to food (in)security status, nutrient adequacy and nutritional status.

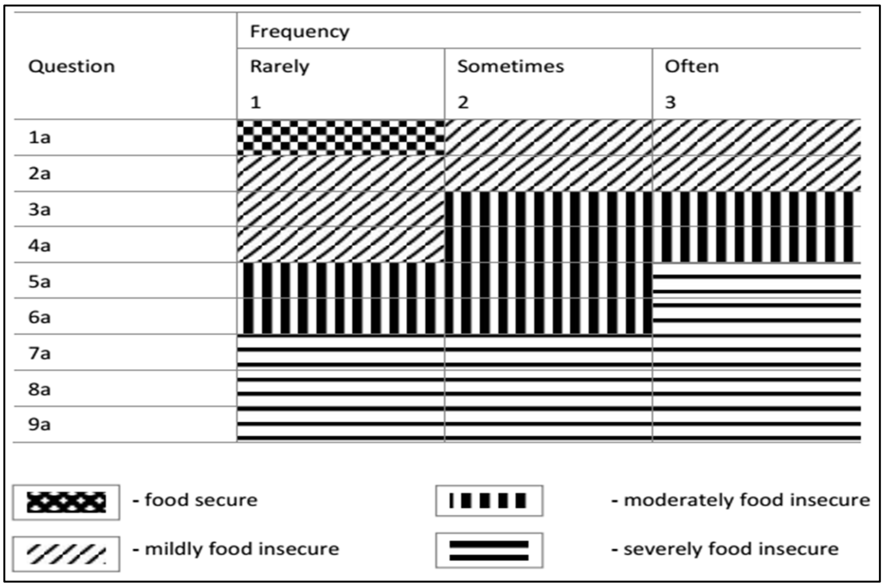
#### 2.1.4.1 Indicators of household food (in)security

Among many indicators of a household’s FNS, Household Hunger Scale, Household Food Insecurity Access Scale, Household Dietary Diversity Score, Coping Strategies Index, and Reduced Coping Strategies Index are the most common examples (Coates et al. 2007a; Deitchler 2010 Ballard et al. 2011; Maxwell et al. 2013, Maxwell et al. 2014).

The Household Hunger Scale (HHS) was developed by the Food and Nutrition Technical Assistance (FANTA) project to measure the household hunger status in in a given area (Ballard et al., 2011). It mainly focuses on the food quantity dimension of food access and does not measure dietary quality. Its effectiveness has been validated across cultures and settings so that can be used universally to compare the level of hunger across communities, countries and or regions (Deitchler 2010; Ballard et al. 2011;

Maxwell et al. 2014). The scales range from 0-6 scores with three standard cut-off points 0-1, 2-3 and 4-6 representing ‘no or little’, ‘moderate’, and ‘severe’ hunger levels, respectively (Ballard et al. 2011).

As food (in)security goes beyond hunger, FANTA established the Household Food Insecurity Access Scale (HFIAS), which includes additional aspects of food (in)security, such as food quality, sufficiency and psychological impacts (Coates et al. 2007a; Maxwell et al. 2013). The HFIAS consists of nine questions focusing on the household food access history termed as ‘occurrence questions’, each of which is contrasted with the ‘frequency questions’ (with three possible answers), which are formulated for the previous four weeks. Hence, there are 0-27 scores to define the level of food (in)security, which ultimately are used as standard cut-off points to assign the assessed target into four categories of food (in)security (Coates et al. 2007a) (Figure 2-2). The HFIAS has been validated across cultures and countries (Knueppel 2010; Psaki et al. 2012), so the mean value of a given site or community or country can be compared against other results of other areas (Coates et al. 2007a).



| Question | Frequency | | |
|---|---|---|---|
| | Rarely<br>1 | Sometimes<br>2 | Often<br>3 |
| 1a | ▦ | ▨ | ▨ |
| 2a | ▨ | ▨ | ▨ |
| 3a | ▨ | ▥ | ▥ |
| 4a | ▨ | ▥ | ▥ |
| 5a | ▥ | ▥ | ▤ |
| 6a | ▥ | ▥ | ▤ |
| 7a | ▤ | ▤ | ▤ |
| 8a | ▤ | ▤ | ▤ |
| 9a | ▤ | ▤ | ▤ |

▦ - food secure

▥ - moderately food insecure

▨ - mildly food insecure

▤ - severely food insecure

Figure 2-2. Classes of food (in)security of households with their cut-off point (Coates et al. 2007a).

The Household Dietary Diversity Score (HDDS) is another indicator that provides information about the economic ability of a household to access a variety of foods, and the adequacy of dietary energy for a given period of time. Studies have shown that an increase in dietary diversity is associated with the economic status and the household food security (household energy availability) (Hoddinot and Yohannes 2002; Hatløy et al. 2000). The HDDS counts the food groups that a household has consumed in a given period of time (Kennedy et al., 2011). Twelve (12) food groups were recommended by Swindale and Bilinsky (2006) to capture the availability of dietary sources for all members of a household. Unlike the HHS and HFIAS, HDDS does not have standard cut-off points to categorize samples into different food (in)security levels (Kennedy et al., 2011), rather the captured scores are grouped into tertiles as 'low', 'medium' and 'high'.

The Coping Strategy Index (CSI) and the Reduced Coping Strategy Index (rCSI) were developed and used in Kenya, Ghana, and Uganda, but have also been validated to assess food (in)security in at least nine other African countries and several others in the Middle East and Asia (Maxwell et al 2008). The CSI and rCSI measure the behavior of households when they fall short of food or of money to buy food. The CSI is constructed by eliciting the coping strategies and then adding information on 'how frequent' and 'how serious' each strategy is (Maxwell and Caldwell 2008; Maxwell et al. 2008). As it is site specific, the CSI has a limitation regarding broader upscaling. Thus, it is reduced to five coping behaviors considered 'universal' in nature to reflect food security, i.e. rCSI. Both the CSI and rCSI are applied by weighting the frequency of each strategy/behavior by their perceived severity, and then summing up the values of all strategies. As the scores reflect the current and perceived future food security status, they are also an appropriate tool for emergency situations when other methods are not practicable or timely available (Maxwell et al. 2008; Maxwell and Caldwell 2008).

#### 2.1.4.2 Indicators of dietary/nutrient adequacy

Dietary/nutrient adequacy refers to the achievement of recommended intakes of energy and other nutrients. It mostly reflects the utilization pillar of FSN. The quality of the food can be assessed in terms of food or food group intakes and diet patterns, or in terms of nutrient consumption and the level of acquiescence with the reference of nutrient requirements. Dietary/nutrient adequacy can be assessed based on different times of reference, i.e. daily, weekly and monthly (WFP-VAM 2008; Tabacchi et al. 2009; Kennedy et al. 2011; Ngala, 2015; WFP-VAM 2015). The selection of methods and indicators depends on the purpose of the analysis, e.g. to assess individuals or a population, the nutrient under study, or the type of distribution of the nutrient intake (WFP-VAM 2008; Tabacchi et al. 2009; Ngala 2015). Among the many existing indicators of dietary/nutrient adequacy, the Individual Dietary Diversity Score (IDDS), Minimum Dietary Diversity (MDD) score, Minimum Dietary Diversity Score for Women (MDD-W) and Food Consumption Score (FCS) are the most popular, as they are cheap, easy and quick to apply (WFP-VAM, 2008; Kennedy et al. 2011; Ngala, 2015; WFP-VAM, 2015).

The IDDS counts the consumption of an individual of specific food groups during the previous 24 hours. It aims at evaluating how the daily dietary intake of the target individual adequately satisfies the physiological requirements of the individual. Several studies have shown the adequacy of the IDDS to estimate an adequate micronutrient intake in different age and sex groups (Hatløy et al. 1998; Mirmiran et al. 2004; Swindale and Bilinsky 2006; Steyn et al. 2006; Arimond et al. 2010).

The MDD for children (WHO 2008) and the MDD-W for women (FAO and FHI 360 2016) are modified IDDS specially designed for infants and women giving special focus on the nutrients required by these given that non-breast feeding (NBF) children under 5 years and women of reproductive age (WRA) are the nutritionally most vulnerable groups because of their specific physiological demands during early growth, pregnancy and lactation (WHO 2008; FAO and FHI 360 2016). Food groups such as proteins and iron can indicate the FNS status of these groups. For instance, WHO (2008) stated that the dietary diversity of children from 6-23 months of age must include foods from four or more food groups out of seven, namely ‘grains, roots and tubers’, ‘legumes and nuts’, ‘dairy products’, ‘flesh foods’, ‘eggs’, ‘vitamin-A-rich fruits and vegetables’, and ‘other fruits and vegetables’. Similarly, FAO and FHI 360 (2016) indicate that women from 15-49 years of age have to consume at least five out of ten defined food groups. These ten food groups are ‘grains, white roots and tubers, and plantains’, ‘pulses (beans, peas and lentils)’, ‘nuts and seeds’, ‘dairy’, ‘meat, poultry and fish’, ‘eggs’, ‘dark green leafy vegetables’, ‘other vitamin A-rich fruits and vegetables’, ‘other vegetables ’, and ‘other fruits'.

Another tool to determine the nutrient adequacy is the weekly Food Consumption Score (FCS), which sums the frequency of nine food groups consumed by a specific individual. The FCS combines dietary diversity, food consumption frequency, and relative nutrition importance of different food groups (WFP-VAM 2008; Wiesmann et al. 2009; WFP-VAM 2015). According to WFP-VAM (2008), the FCS can be constructed by simply considering all groups as equally important or giving different weighting values for the different food groups based their physiological importance, and then calculating the FCS of the sample individual. The final score is used to determine the adequacy by using a standard cut-off point produced by the WFP, which assign scores 0 to 21, 21.1-35.0 and >35, as 'poor', 'borderline' and 'acceptable' adequacy, respectively (WFP-VAM 2008).

After determining the adequacy level with the above indicators, a further evaluation of the adequacy status of some specific nutrients will follow to address the nutrition security of a given community.

Although all macro- and micro-nutrients are important to ensure a healthy life and should be consumed in sufficient quantities in a balanced diet, the deficiency of some is more critical than that of others. According to WFP-VAM (2015), three nutrients, namely protein, vitamin A, and heme iron, are selected not only for their higher nutritional importance, but also because these can be easily grouped in the food consumption history of individuals. For instance, regarding iron, heme iron can only be found in meat and fish, and is well absorbed by the organism (10-30%). In contrast, non-heme iron is found in cereals, fruit, vegetables, and dairy products, and only 1-5% is absorbed by the organism (WHO and FAO 2004). Thus, the sum of the relative occurrence and number of food groups as potential sources of each nutrient helps to evaluate their deficiency pattern in each diversity category and in the whole population.

#### 2.1.4.3 Indicators of nutritional status

The nutritional status of the target community is captured either directly via clinical assessment or indirectly via anthropometric assessment. The direct assessment such as blood sample analysis is often costly and requires a well-stablished infrastructure, which is rarely available in most developing countries (Gibson 2005). Hence, indirect indicators such as anthropometric assessment are easily applicable tools, although less precise, to determine the nutritional status of a given community. The FANTA project regards anthropometry-based nutrition assessment as an inexpensive, easy and non-invasive tool to capture the nutritional status of an individual or a population group (Cogill 2003), as a physical or morphological size of any individual is a function of the type and amount food consumed in given period of time. Hence, anthropometry is used to assess and predict performance, health, and survival of individuals, and reflects the economic and social well-being of populations.

Anthropometric evaluations are usually performed on the two most vulnerable groups, i.e. the NBF children under 5 years and women of reproductive age (WRA). Each of these groups has their own indicators. For the children, age, weight, and height comprise the z-score developed by the WHO Multicenter Growth Reference Study specifically for NBF children under 5 years (59 months) (WHO 2006). According to WHO (1999), the z-sore is calculated as a deviation value of an individual's anthropometric measurement at a given age from the median of values of the children at that specific age of and divided by the standard deviation the specific population. Using the weight and height measurements of children, three different anthropometric indicators can be computed to determine the nutritional status of each sampled child, namely weight-for-height z-score (WHZ), weight-for-age z-score (WAZ) and height-for-age z-score (HAZ) (WHO, 2006). Using these scores, the prevalence of child wasting (thinness or marasmus), underweight and stunting can be determined (Gorstein et al. 1994). The WHO developed a standard cut-off point for each of the z-scores to differentiate the status and degree of nutrition insecurity (Table 2-1).

Table 2-1 Child growth cut-off points for nutritional status (WHO, 2006)

| Score | <-3 z-score | <-2 and ≥-3 z-score | ≤-2 and ≥+2 z-score |
|---|---|---|---|
| WHZ | Severely wasted | Moderately wasted | Normal |
| WAZ | Severely underweight | Moderately underweight | Normal |
| HAZ | Severely stunted | Moderately stunted | Normal |

*WHZ = weight to height z-score, WAZ = weight to age z-score, HAZ = height to age z-score.*

Besides weight and height measurement, head circumference, mid-upper arm circumference and occurrence of edema can also be used as indicators of a child's nutritional status (Cogill 2003; Gibson 2005; Pandve and Singru 2012).

For women of reproductive age, the Body Mass Index (BMI) is the most common indicator used (WHO 1995; Prista et al. 2003; Gibson 2005). It is calculated by dividing the weight of the individual measured in kilogram by the square of her height measured in centimeter. The individual BMI value is then compared to the WHO standard cut-off points to assign it into one of the five nutritional status categories (WHO 1999; FANTA 2016) (Table 2-2). Hence, the proportion of individuals in each category is used to determine the nutritional status of the overall community.

Table 2-2. Nutritional categories of body mass index for non-pregnant, non-lactating women of reproductive age. Adapted from WHO (1999) and FANTA (2016)

| Nutritional status category | BMI (kg/m$^2$) |
|---|---|
| Malnutrition | <18.50 |
| Severe malnutrition | <16.00 |
| Moderate malnutrition | 16.00 - 16.99 |
| Mild malnutrition | 17.00 - 18.49 |
| Normal | 18.50 - 24.99 |
| Overweight | ≥25.00 |
| Obese | ≥30.00 |

In addition to weight and height, waist circumference, waist-to-hip ratio, elbow amplitude, and knee-heel length can also be used as a nutritional status indicator of WRA in a given community (Molarius and Seidell 1998; Gibson 2005; Sánchez-Garcia et al. 2007).

## 2.2 Agroforestry

### 2.2.1 Concept of agroforestry

Agroforestry is an ancient land, estimated being in use for more than 1300 years (Brookfield and Padoch 1994), where current practitioners are estimated to be more than 1.2 billion worldwide (Zomer et al. 2009). Essentially, agroforestry allows farmers to produce several goods and services in the same unit of land in an integrated manner to address a broader array of demands. Since its modern scientific re-foundation in the 1970's, many definitions have been coined (King 1978 cited in King 1979; King 1979; Lundgren 1982 cited in Gold and Hanover 1987; Young 1983; Nair 1985; Somarriba 1992; Leakey 1996) which, despite minor differences, agree on essential features that characterize an agroforestry system:

- The presence of at least one woody perennial component and at least one annual crop or animal component
- The components are purposefully managed
- The system generates more than one output
- Interaction exists among components.

Based on these features, the World Agroforestry Centre proposed a working definition of agroforestry. It is *"(...) an ecologically based natural resource management system that integrates trees (for fiber, food and energy) with crop and/or animal on farms with aim of diversifying and sustaining income and production while maintaining ecosystem services*" (ICRAF 2000).

### 2.2.2 Classification of agroforestry

The differences in content and scope of the various definitions of agroforestry are challenged by an intrinsic quality, which is its broad variation across sites. Depending on the available resources, management purpose, and the social, economic, cultural and other attributes of an individual, family or any other human practitioner group, resulting agroforestry systems and practices vary widely. Homegarden, *taungya*, alley cropping, improved fallow, *kebun-talun*, coffee-shade system, shelterbelt, *dehesa*, and parklands, are among the well-known variants of agroforestry. For instance, although they are all homegardens (a well characterized agroforestry practice), the *chagga* of Tanzania is neither similar to the *pekarangan* of west Java nor to the *guwaro* of Ethiopia.

Hence, to distinguish these variations, several attempts of systematic classification have been proposed (King 1979; Grainger 1980; Torres 1983; Somarriba 1992; Nair 1993; Sinclair 1999). For instance, Nair (1985) used structural, functional, socio-economic and ecological criteria, while Dwivedi (1992) used physiognomic, historical, and floristic principles. Some of these approaches are developed below for further elucidation.

The structural criterion considers two aspects, i.e. components and arrangement. Component-wise, all agroforestry systems/practices consist of at least two components, one woody perennial and one annual, either crop or animal. Based on this, three major groups of agroforestry exist, i.e. 'agrosilvo' (combinations of trees and crops), ‘silvopastural’ (combinations of trees and animals), and agrosilvopastural’ (combinations of trees, crops and animals) (King 1979; Nair 1985; Nair 1993; Sinclair 1999).

Based on component arrangement, often deliberately under specific spatial and/or temporal criteria, when both vertical and horizontal dimensions are considered, a random, zonal or multi-storey arrangement is possible (Nair 1993; Sinclair 1999; Torquebiau, 2000). In the random type, the perennial woody component possesses an arbitrary position with respect to the annual crops and/or or animal components. For instance, in the parklands of East Africa, *Faidherbia albida* among other trees are scattered across the farming field, as well as several *Quercus* species in the *dehesa* system of Spain (Ruiz-Perez 1986). In the zonal type, the components are arranged arbitrarily according to the features and a pre-established purpose of each as in the case of the shelterbelts, alley cropping and hedgerows in many tropical countries (Kang and Wilson 1987; Bannister and Nair 1990; Nair 1993). In the multi-storey arrangement, woody and other components might show more than one distinct layer or stratum as in the above-mentioned *chagga*, *pekarangan*, and *guwaro* homegardens. In this type of arrangement, it is possible to concentrate a higher number of species and intensify and diversify overall production (Watson and Eyzaguirre 2002). In temporal terms, the possible combinations of components in a given agroforestry system and practices are limited by their life span or rotation period (Figure 2-3) (Nair 1985; Nair 1993; Sinclair 1999).

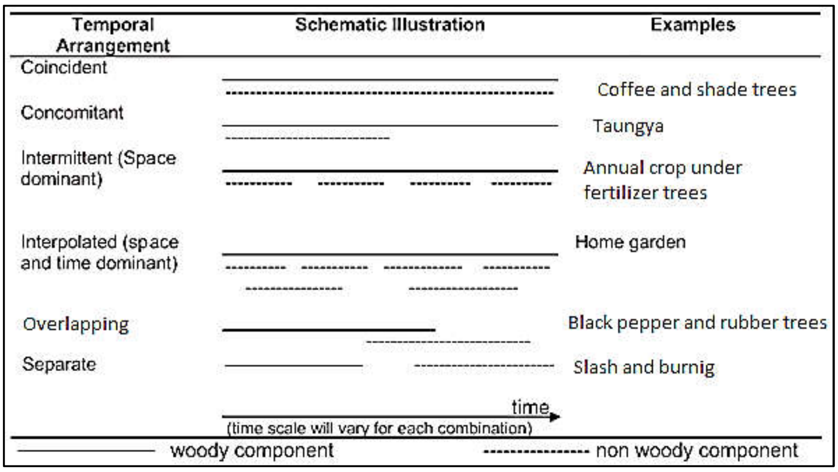


Figure 2-3 Classification of agroforestry practices based on temporal criteria (Adapted from Nair (1993))

Functional classifications depend on the primary function, purpose or outputs of the perennial woody component, which are mainly productive and protective (Nair 1993; Sinclair 1999). As for the productive function, trees are planted to produce goods like food, fodder, fuel, wood, fiber, fertilizer, and non-woody products. For instance, the *Quercus ilex* is kept to produce sweet acorn as feedstock in the *dehesa* systems, and *Q. suber* to produce cork (Ruiz-Perez 1986). Functions are beyond items or goods production, e.g. nitrogen-fixing trees may increase productivity while reducing the cost of inorganic fertilizer (Poschen 1986; Ojiem et al. 2007). Protective functions refer to trees planted or maintained to guard other crops from harm, among these are shelterbelts, wind breaks, planted hedgerows, etc. (Nair 1993; Bird 1998). For instance, alley cropping on the Haiti hillsides abates soil erosion (Bannister and Nair, 1990), or the tree *Grevillea robusta* is used to support *Piper nigrum* and other climbing spices in Tanzania (Reyes et al. 2009).

In practice, most farming trees offer a large range of side benefits and functions. For example, leguminous trees in Ethiopian coffee agroforestry offer shade, temperate environment, and increase moisture while fertilizing the soil (Muleta et al. 2011). *Moringa stenopetala* in the Konso community of Ethiopia provides edible leaves used as staple food, and is also used to stabilize the soil in hilly landscapes (Jiru et al. 2006; Mulat 2013). Such types of AFP are difficult to assign to the functional types, and are thus better labeled as multipurpose.

Although functional and structural classifications are the most commonly used, other approaches exist. For instance, based on the ecological setup where the practice occurs, they can be classified as highland, mid-altitude, and lowland agroforestry systems, or as tropical, Mediterranean, temperate and alpine agroforestry systems (Sinclair 1999). Similarly, physiognomic attributes can also be used, e.g. wetland, arid, humid, or desert agroforestry systems (Dwivedi 1992). Socioeconomic premises can also be applied to distinguish different systems, e.g. subsistence vs. commercial, small-scale vs. large-scale, low-input vs. high-input, traditional vs. modern, etc. (Nair 1993). Despite the existence of these numerous classification approaches, it should be clear that they "*are by no means independent or mutually exclusive. Indeed, it is obvious that they have to be interrelated.*'' (Nair 1993).

Another aspect of agroforestry classification is the trend of using the term 'system', 'sub-system' and 'practice' equivocally, often as a synonym to describe the certain forms agroforestry. Even if there is no standard use of these terms, Nair (1985) differentiated them in hierarchical arrangements: System refers to a tree-based land use that extends over a locality or wider agroecological zone, whereas the latter two exhibit a lower order under the 'system' with a smaller area, form and complexity. In this study the term 'practice' is used, as the study covers relatively smaller areas considered as a locality or agroecology.

## 2.3 Agroforestry for food and nutrition security of small farming households

As noted above, the attainment of the five pillars is a pre-requisite for achieving FNS. As a variety of AFP exist, each may have a different stake in relation to these pillars. Hence, in this section the potential of agroforestry towards the improvement of each pillar is reviewed, and some specific examples from tropical countries, mainly Ethiopia, are provided.

Agroforestry can contribute to food availability directly via the production of food from the perennial component(s), and/or through the enhancement of food production of the annual crop and/or animal/insect component(s) (Jamnadass et al. 2013; Sarvade et al. 2014). Although often disregarded, an example of the former is the enset-coffee homegarden of the Sidama and Gedeo communities in southern Ethiopia that include the perennial species enset (*Ensete ventricosum*), which serves as staple food for about 15 million people in the region (Abebe 2013). More frequently, and alongside the direct provision of edible products, agroforestry can enhance the yields of other food-crop component(s) of the system, for instance by including nitrogen-fixing species, e.g. in Sudan *Faidherbia albida* has increased the harvests of surrounding cereals and groundnut up to 200% (Fadl and El sheikh 2010). Likewise, in Malawi, maize cultivated in intercropping with *Gliricidia sepium* is reported to have increased yields from 40% to 300% (Maclean et al. 1992; Rao and Mathuva 2000; Akinnifesi et al. 2006; Makumba et al. 2006; Beedy et al., 2010). Also, agroforestry can augment the provision of feedstocks for the animal component, and increase the animal production-derived foods such as meat, milk, and honey. In East Africa, more than 200,000 smallholder dairy farmers use supplementary feed from fodder shrubs (Place et al. 2009). In Cagayan de Oro, Philippines, feedstock resulting from combining fodder grasses and trees, e.g. *Gliricidia sepium,* surpasses the quality of grasses, improves the health and vigor of livestock thus preventing disease and pests risks, and spares farm labor for herding and tethering animals (Bosma et al. 2003).

Considering the contribution of agroforestry to food access, in cash-crop-dominated areas, these species tend to be the prime source of income of farmer livelihoods, which is later used to buy food from the markets. Accordingly, some agroforestry systems/practices may focus on the production of highly valuable cash products, e.g. *Coffea arabica* and *Theobroma cacao*, but in the majority of cases, the array of merchantable agroforestry products is wide, i.e. fruit, stimulants, spices, wood, resins, etc., and can generate a considerable amount of cash by selling. For instance, in Bushbuckridge, South Africa, famers sell the fruit *Sclerocarya birrea* harvested from their parkland agroforestry plots, as it is the prime material of a valuable cream liquor that generates cash for their household (Shackleton 2004). *Dacryodes edulis* and *Vitellaria paradoxa* are among the most widespread indigenous merchantable fruits harvested from agroforestry parkland in West Africa (Schreckenberg et al. 2006; Trade Hub and African Partners Network 2014). In East Africa, *Catha edulis,* often associated with coffee on small farmer plots, generates regular income as it is mostly sold in local markets, thus increasing the farmers' economic and food acquisition capacities (Dessie 2013; Beghin and Teshome 2016; Gyau and Muthuri 2016). Farmers in West and East Africa grow timber trees like *Eucalyptus globulus*, *Eucalyptus grandis*, *Tectona grandis*, and *Cupressus lusitanica* together with understory crops to produce timber, poles, posts and other wood and fiber products (Duguma and Hager 2010; FAO 2011; Mathu 2011; Luukkanen and Appiah 2013). In Kenya, trees grown in farmland like *Azaridachta indica*, *Moringa oleifera* and *Prunus africana* generate products of medicinal value used for self-treatment but also for selling (Muriuki et al. 2012). Some perennial components can contribute indirectly to other species production and the generation of income by supporting the plants physically, as in Tanzania where farmers use trees such as *Grevillea robusta* and *Gliricidia sepium* to support *Piper nigrum* (Reyes et al. 2009), or to encourage their physiology through shade, as is the case with coffee and cacao (Muleta et al. 2011; Asare, 2016).

The food utilization pillar relies on the quality and safety of food on the one side, and on consumer health and physiological assimilation capacity on the other. The broad recognition of its importance triggered different measures to alleviate problems associated with this aspect. Among these, increasing and diversifying the consumption of fruits, vegetables and animal products is reported to be the most affordable and sustainable approach to abate micronutrient deficiency (Thompson and Amoroso 2010; Susila et al. 2012). Jamnadass et al. (2013) identified trees in agroforestry as good sources of food, mostly in form of fruits, nuts and leafy vegetables, which usually are rich sources of micronutrients. Using a data collected from 21 African countries during the period 2003–2011, Ickowitz et al. (2014) found a strong correlation between tree cover and dietary diversity. Abebe (2005) and Méndez et al. (2001) observed a great diversity in homegardens, mainly of vegetables, fruits, and spices, which are also rich in nutrients.

Agroforestry can also enhance the availability of animal-based protein, vitamins and minerals from meat, fish, dairy and other animal products through the production of supplementary fodder and forage. A number of reports state that the inclusion of fodder and forage from trees and shrubs into the animal feed has enhanced the animal production yield of households (Dixon et al. 2010; Wambugu et al. 2011; Franzel et al. 2013; Dawson et al. 2014; Sarvade et al. 2014). In general, agroforestry potentially improves the availability of diversified foods, which in most cases compensate the nutrients lacking in starchy staple diets.

Regarding the safety and effective utilization of food, proper cooking is a vital factor, as this helps to release the energy and nutrients contained in food, but also to be clean and safe for cosumption. The FAO (2008) confirms that firewood and charcoal from trees are crucial for the survival and well-being of about 2 billion people worldwide. In this regard, the trees in agroforestry can offer locally available, affordable and renewable fuel. Thorlakson and Neufeldt (2012) observed that small-scale agroforestry plot holders in Kenya have less need for purchasing fuelwood or for collecting it from natural stands, and therefore have more time for other activities. Kamp et al. (2016) compared the production of fuelwood from agroforestry and two biogas installations of smallholders in Ghana where the former was a more attractive alternative in terms of soil fertility, net soil carbon emission, labor requirement, resource use efficiency, and global renewability.

Food stability is normally achieved when the other three pillars have attained relative stability. In agroforestry, the diversity of species and the presence of the perennial component underpin the system capacities to achieve and stabilize the previous three pillars. The presence of more than one edible species, each with a different phenology and thus harvesting calendar results in a relatively consistent availability of foods across the year. This is key for most agrarian regions of the developing world, which tend to experience seasons of both food surplus and food shortage (Haile 2005; Sarker 2016; Sassi 2017). For example, the Konso community in southern Ethiopia cultivates *Moringa stenopetala* in diverse agroforestry arrangements, whose main function is filling the gaps in the annual food supply (Förch 2003). Similarly, *Vitellaria paradoxa* and *Sclerocarya birrea*, traditional components of agroforestry parklands, are reported as potential food sources of local communities during droughts and crop failure in several parts of Africa (Maranz et al. 2004; Mojeremane and Tshwenyane 2004; Jamnadass et al. 2013). A higher diversity of cash crops produced during a broader harvesting calendar and the availability of sellable products secure income for farmers and subsequent access to the foods available on local markets.

Moreover, the higher diversity of components, the complex interaction among them, and the multiple inputs received and outcomes generated coupled with the physiological robustness of trees makes agroforestry systems less vulnerable and more resilient to environmental shocks than monocrop systems. According to Jamnadass et al. (2013), the diversity and interaction among agroforestry components mitigate the impact as each component reacts differently to natural turbulences. Hence, farmers in Niger argue that increasing the number of tree species per purpose insures them against ‘function failure’ in their agroforestry systems, so even in the drier years some species will provide the expected function (Faye et al. 2011). In Kenya, smallholder farmers practicing agroforestry for soil conservation, fertility increase and fuelwood provision identified more coping strategies when exposed to climate-related shocks than those who did not (Thorlakson and Neufeldt 2012).

Similar to the previous four pillars, the polyculture cropping nature of agroforestry contributes to households’ food sovereignty through allowing them to cultivate crops (food and non-food) that are demanded by both the household and the market or external environment. According to Wilson (2015) and Altieri et al. (2012), such agroforestry systems improve the quantity of diversified food output and production stability while saving smallholding farm households from depending on inaccessible markets. On the other hand, Noordwijk et al. (2014) stated that the cash generated from multispecies plots of agroforestry have a potential to ensure the income security of the households who can define their own local food security and ultimately attain food sovereignty by purchasing what they need.

# 3 DESCRIPTION OF STUDY AREA AND SAMPLING PROCEDURE

## 3.1 Study area

The study area Yayu is located in the Illubabor zone of the Oromiya state, south-western Ethiopia, between 8°10’ – 8°39’ N and 35°30’ – 36°4’ E. The area was registered by the United Nations Educational, Scientific and Cultural Organization (UNESCO) in 2010 as a biosphere reserve for the in-situ conservation of wild *Coffea arabica*. It covers about 168,000 ha in six *woreda*[1], namely Algae Sachi, Bilo-Nopa, Chora, Doreni, Hurumu, and Yayu (Gole et al. 2009). The area has a rolling topography, altitude ranges from 1140 to 2562 m.a.s.l., and it is crossed by three major rivers, i.e. Geba, Dogi, and Sese (Figure 3-1). The climate is hot and humid, mean annual temperature is 22.5°C, ranging between the average extremes of 18.46°C and 21.25°C. The area exhibits a unimodal rainfall pattern with a mean annual precipitation of 2100 mm (Gole 2003) (Figure 3-2). Dominant soil groups include nitosols, acrisols, vertisols, and cambisols (Tafesse 1996).

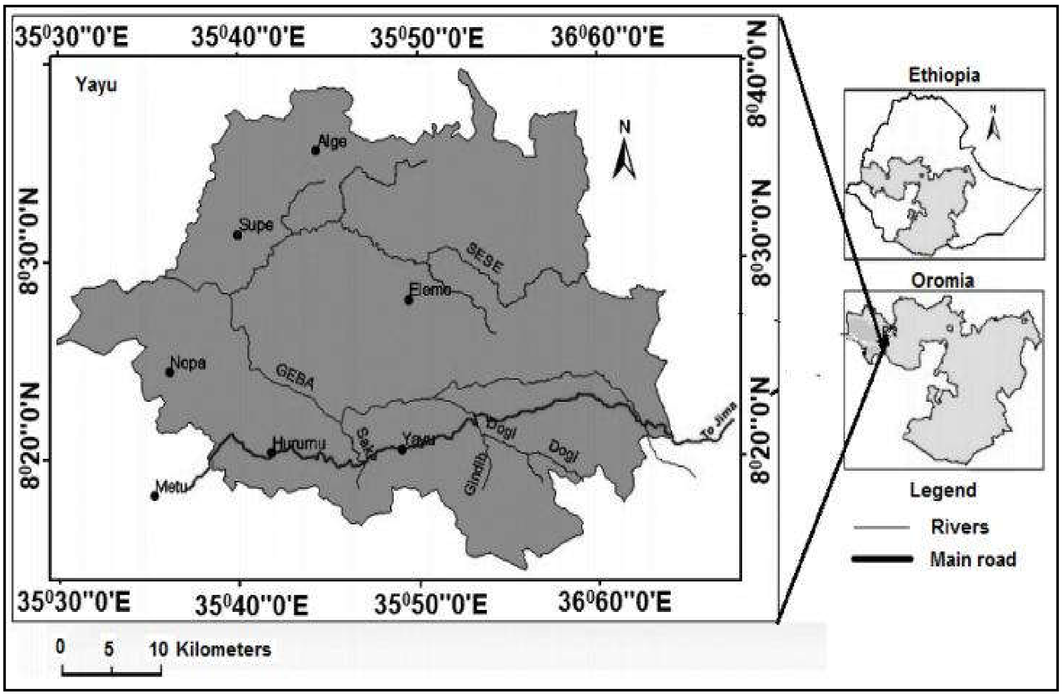


Figure 3-1. Location of Yayu in Ethiopia. Adapted from Gole et al. (2009).

In 2007, around 310,000 people lived in the six *woreda* in the Yayu biosphere reserve (CSA 2007). The Oromo ethnic group dominates and is considered indigenous.

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[1] A *woreda* is the second smallest administrative unit after *kebele*. *Kebele* is the smallest administrative unit equivalent to *ward*.

The Amhara, Tigreway and Kembata people exist in significant numbers, as they migrated from other parts of the country due to the government's forced resettlement program of 1984 (Kassa 2004). Orthodox christian, muslim, protestant and indigenous beliefs are evenly practiced (Tulu 2010). Currently, the population of Yayu is booming due to the high birth rates (about 3.2% per annum) (Tafesse 1996) and the intense internal migration due mainly to the thriving infrastructural development (Tadesse 2015) such as the construction of fertilizer and coal mining factories, a network of roads planned to ease the trade of coffee, and a forthcoming hydroelectric dam on the Geba River (Bacha 2014).

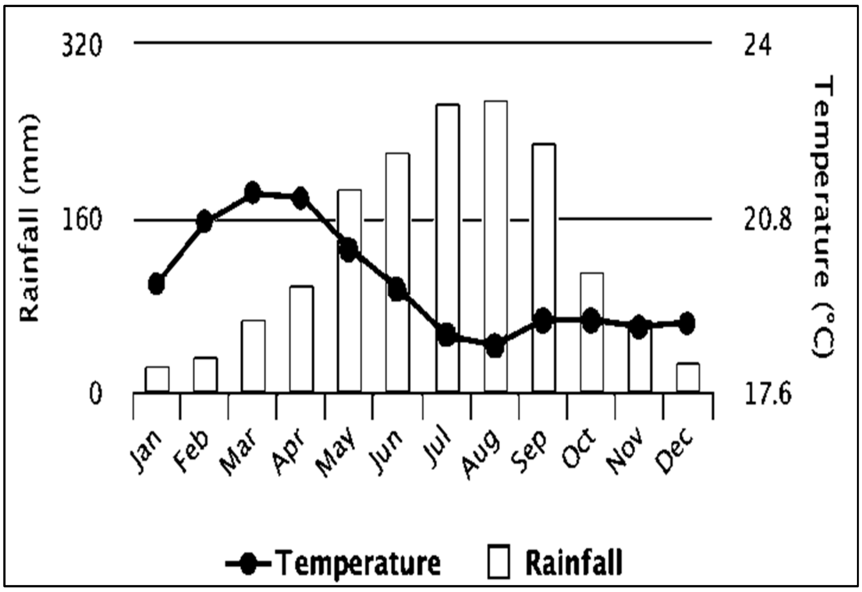

Figure 3-2 Annual temperature and rainfall distribution pattern of Yayu (World Bank Group, 2017)

The main livelihood source of Yayu smallholders is coffee-based agriculture, which employs over 90% of the active labor of the area (Assefa 2010). Most coffee plots are small. It is estimated that more than 60% of the population depends on coffee production and coffee-related activities such as collection, processing, and marketing (Gole 2003; Ilfata 2008). Besides *Coffea arabica* and other cash crops like *Catha edulis*, smallholders produce annual crops such as *Zea mays*, *Sorghum bicolor*, *Eragrostis tef*, and other cereals and pulses.

The Yayu landscape is a mosaic with forest and agriculture as the major land-use types (Table 3-1).

Table 3-1. Land use in Yayu (%). Adapted from Assefa (2010)

| Major land-use type | Form | Percentage |
|---|---|---|
| Forest | Undisturbed natural forest, coffee production plots | 69% |
| Agriculture | Annual crops including multipurpose trees on farmland | 14% |
| Homestead farm | Homegardens | 12% |
| Other | Grazing land, plantation forest | 5% |

Forests cover most of the Yayu area, and comprise four major variations, i.e. undisturbed natural forest, semi-forest coffee systems, fully managed for coffee production, and old secondary forests (Gole et al. 2009). The forests belong to the Eastern Afromontane type identified as one of the 34 hotspot areas in the world by Conservation International (BirdLife International, 2012). The area is well conserved and particularly important as a gene pool of wild coffee (Gole et al. 2008; Senbeta et al. 2013). Recognizing these attributes, in 2010 UNESCO registered the Yayu area as the ‘Yayu Coffee Forest Biosphere Reserve’. The reserve consists of three concentric zones, i.e. core, buffer and transition zones covering about 28,000, 22,000, and 118,000 ha, respectively (Gole et al. 2009). The above-described land-use types are allowed in the outer zones (transition and buffer), but in the inner (core) zone intact forests are maintained and no activities are permitted there (Gole et al. 2009).

In terms of food and nutrition security, the Yayu area is relatively food secure. No incidents of food insecurity have been reported in the last 15 years (Reliefweb. 2002; FEWS NET, 2005-2017). Instead, it is regarded as productive and often a destination for relocated communities exposed to recurrent famine and droughts in other parts of the country (Gizaw 2013). However, much less is known of the peoples’ nutritional status, its relation to the existing livelihoods, and the potential of these to fulfill nutrition demands. Hence, this study assesses the potential contribution of agroforestry-based coffee practices to local households’ nutrition security.

Regarding the food and cash availability calendar, Yayu area exhibits two major food and/or cash surplus and shortage seasons. The surplus season refers to the post-harvest period of coffee and cereal crops between June and September, whereas the pre-harvesting period from January to March is regarded as the shortage or lean season.

## 3.2 Sampling procedure

Prior to *kebele*[2] selection, potential sources of errors were listed to minimize their effect on the results of the study. Mainly, the relative distance of the small farming households to the forest in the core zone and market facilities was assumed to have significant influence (Abebe 2013). Thus, *kebele* sampling was stratified based on proximity to the forest and to the market. Every *kebele* with a forest (core zone) in its jurisdiction was considered 'near to forest', otherwise as 'far from forest'. Similarly, those *kebele* that were located near the transportation road[3] were assumed to have better access to markets, and considered as 'near market', otherwise 'far from market'. On this basis, all *kebele* in the reserve were classified into four categories with two proximity criteria each with two levels (near and far), and then two *kebele* from each class were selected subjectively based on the logistics and time frame available for completing data collection (Table 3-2). Sample size and units of each activity are presented under the methodology topics of each activity (Table 3-2 and Figure3-3).

Table 3-2 Size, proximity classes and topographical attributes of 8 sample *Kebele* in Yayu

| **Proximity class** | **Name of sample *kebele*** | **Altitudinal range (m.a.s.l)** | **Sample size (n)** |
|---|---|---|---|
| Near to forest and near to market area (NN) | Wabo | 1570 to 1624 | 27 |
| | Wutete | 1565 to 1672 | 45 |
| Near to forest but far from market area (NF) | Sololo | 1624 to 1688 | 43 |
| | Wangene | 1562 to 1890 | 44 |
| Far from forest and near to market area (FN) | Weyira | 1789 to 1973 | 26 |
| | Werebo | 1725 to 1892 | 45 |
| Far from forest but far from market area (FF) | Beteli Gebecha | 1754 to 1819 | 45 |
| | Elemo | 1906 to 1981 | 25 |

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[2] A *kebele* is the smallest administrative unit of Ethiopia, similar to a *ward*, a neighbourhood or a localized and delimited group of households.

[3] The all-weather road from Metu to Bedele

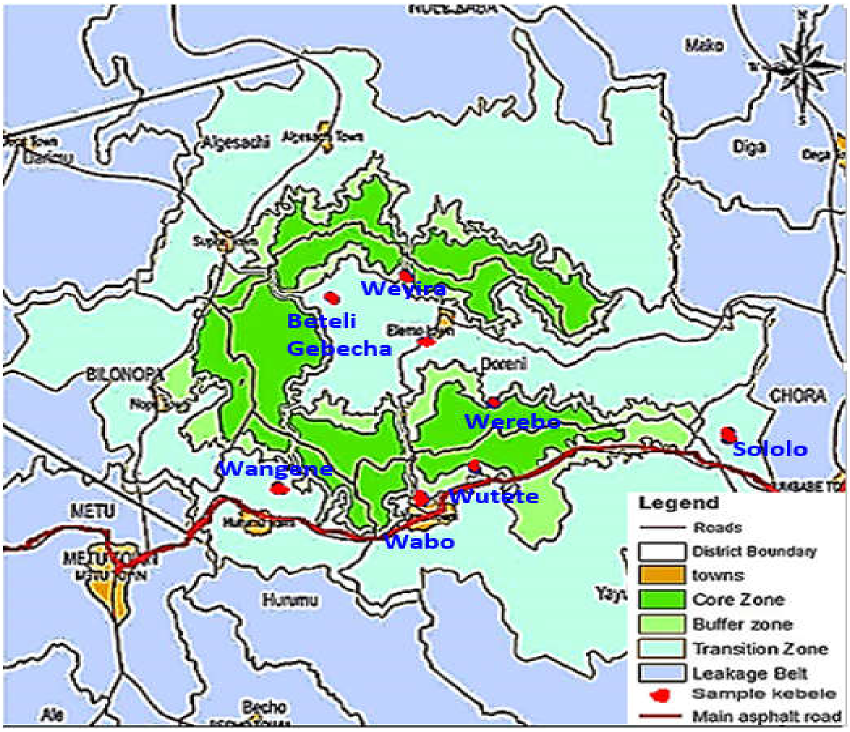

Figure 3-3 Map of sample *Kebele* with reference to the three zones of the Yayu Coffee Forest Biosphere Reserve and road facilities.

# 4 POTENTIAL OF LOCAL AGROFORESTRY PRACTICES FOR FOOD AND NUTRITION SECURITY OF SMALLHOLDING FARMING HOUSEHOLDS OF YAYU, SOUTH-WESTERN ETHIOPIA

## 4.1 Introduction

During the last decades, agroforestry has received increased attention as a viable option to enhance food security while enhancing the adaptability of small-scale farmers to social-ecological hazards such as climate change (section 1.1). The potential of its multiple functions and uses to contribute to the strengthening of the five pillars of food and nutrition security were highlighted in section 2.2.3. These are (i) The presence of perennial staple food species in the system, e.g. *Ensete ventricosum*, *Musa spp.*, and *Moringa stenopetala*, or *Manihot esculenta* increases the availability of food. In most of the sub-Saharan countries, such species serve as a staple food for a large number of people (section 2.2.3). (ii) The complexity of agroforestry systems allows the presence and integration of diverse species that provide cash to the farming households, which directly enhances their access to market foods, as is the case of *Coffea arabica*, *Theobroma cacao* or *Catha edulis* (section 2.2.3). (iii) The nutritional demands are enhanced, as agroforestry increases the availability of fruit, leaves, nuts and other nutrient-rich foodstuffs. In addition, agroforestry trees are also important for providing locally available fuel for food cooking, which catalyzes the release of nutrients (section 2.2.3). (iv) Agroforestry can reduce ecological and socio-economic vulnerability, and increase the resilience of the smallholding farming households because of their broad and divergent responses of the various species and the interactions among these (section 2.2.3). (v) Agroforestry enables smallholders to grow a diversity of food crops based on the demand of the household, and reduces the level of dependency on markets. In addition, it enables incorporating cash crops, which contribute to the income security of the households so they can afford to purchase food according to their needs. In both scenarios, the food sovereignty pillar of smallholders is enhanced (section 2.2.3).

Agroforestry practices vary widely in composition, structure, and functions depending on the biophysical, ecological, social, economic and cultural settings where they occur. Hence, taking into account this site specificity is key before attempting any upscaling. As Mbow et al. (2014) emphasized, although agroforestry has a considerable potential to improve food security, ‘’ (…) *not all agroforestry options are viable everywhere*”. Therefore, before recommending or promoting any agroforestry practice for a certain place or community, it is crucial to characterize and recognize its features, attributes, and performance.

In Ethiopia, a wide variety of local/traditional AFP also exists, with great potential to contribute to the food and nutrition security of the involved communities. Many studies exist on the different forms of homegardens across the country (Asfaw 2001; Abebe, 2005; Mekonnen et al. 2014; Bajigo and Tadesse 2015; Mengitu and Fitamo 2015). Croplands with scattered trees of *Faidherbia albida* are the oldest form of indigenous parkland agroforestry, and are still present in the central and eastern parts of Ethiopia (Poschen 1986; Tesemma 2013; Bishaw et al. 2013). Similarly, the enset-coffee gardens practiced by the Gedeo people are well-known as they support millions of livelihoods in the most densely populated areas of the country (Abebe 2005; Asfaw and Ågren 2007).

The traditional coffee production system in south-western Ethiopia is another example of a well-established traditional agroforestry practice (Gole et al. 2009). In Yayu, 60% to 80% of the rural households rely on coffee agroforests for their livelihoods (section 3.1). Concerning the abilities of these practices/systems to offer FNS, in the last 15 years the area has not been identified as chronically food insecure (Reliefweb 2002; FEWS NET 2005 -2017). Rather it has served as a potentially productive area for relocating communities exposed to recurrent famines and droughts from degraded areas of the country (Gizaw 2013).

The vegetation cover of the area is relatively well conserved with large areas of intact forests intermingled with wild coffee plants. Due to this, the area has registered by an UNESCO’s as Yayu Coffee Forest Biosphere Reserve since the year 2010 (See section 3.1). The adequate integration of human utilization and environmental conservation makes the system one of the best performing traditional agroforestry practices/systems of Ethiopia (Muleta et al. 2011; Senbeta et al. 2013). However, these systems coexist with other farming systems such as fields with annual crops, farmlands with scattered trees, homegardens, woodlots, grazing lands and fallows (Table 3-1).

During the last two decades, a number of studies have been conducted in the Yayu area, mostly focusing on ecology, biodiversity and conservation (Taye 2001; Yeshitela and Bekele 2002; Gole, 2003; Senbeta et al. 2005; Senbeta and Denich 2006; Gole et al. 2008; Etissa 2010) with less attention on local agroforestry and other farming systems despite these being the provider of livelihoods in the local communities and the basis of forest use. Therefore, this study aimed to characterize the local AFP of the smallholding farming households in Yayu, emphasizing their potential role for food and nutrition security. This objective includes the identification of predominant AFP and their uses, the main species component of each practice, their structural arrangement and management, use of species, and their respective potential for food provision and cash acquisition.

## 4.2 Materials and methods

### 4.2.1 Sampling

Lacking recent population data, each sample area comprised at least 10,000 inhabitants, hence a total of 300 smallholding farm households were randomly selected from 8 *Kebele*[4] (section 3.2) located within the Yayu biosphere reserve. *Kebele* sampling was stratified considering the relative distances of the households to the forest core zone and market/road, as these two were assumed to have significant influence on agroforestry composition and functioning (Abebe 2013). Thus four categories, based on two criteria (near and far) were created (Table 3-2 and Figure 3-3).

### 4.2.2 Data collection and analysis

Data collection was conducted from December 2014 to February 2015. A household survey and key informant interviews were applied to understand the rationale of local farming and to identify the predominant AFP. The household head was questioned on biographic, demographic, social, economic, geographical and biological attributes of the household and the agroforestry plots. The characterization of AFP included location, size and spatial arrangements of the components, tree species and obtained products, and uses and marketability of these. Field observation complemented data gathering.

Plant species identification was supported by a local taxonomist and specific literature (Mooney 1963; Mesfin and Hedberg 1995; Kelecha 1977; Bekele 1993; Bekele 2007; Teketay et al. 2010). The structural arrangement of the AFP was determined using the stratification described by Das and Das (2005). Utility groups were matched used the functional groups set by Mendez et al. (2001) and Abebe (2013). The food edibility potential was evaluated in two steps. Species were identified as edible and non-edible comparing first-hand observation with secondary resources (Bekele 2007; Teketay et al. 2010; Molla et al. 2011; Senbeta et al. 2013). The 'edible' category was further subdivided into 'potentially edible' and 'active food' species. The former refers to edible plant species not primarily used as food, while the latter refers to species primarily cultivated for food. 'Active food' was further re-classified into 10 plant food groups

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[4] A *kebele* is the smallest administrative unit of Ethiopia, similar to a *ward*, a neighbourhood or a localized and delimited group of households.

according to FAO (Kennedy et al. 2011): ‘cereals’, ‘white root and tubers’, ‘vitamin-A-rich vegetables and tubers’, ‘dark green leafy vegetables’, ‘other vegetables’, ’ vitamin-A-rich fruits’, ‘other fruits’, ‘legumes, nuts and seeds’, ‘sweets’, and ‘spices, condiments, and other food & beverage additives’ .

The potential of each agroforestry practice to generate income was estimated in two steps. First, we assesed the amount and major sources of annual income of the household, both on farm and off farm, establishing the relationship with the species and products of each AFP. Second, we listed all species were listed and the actual marketability status evaluated by classifying them into three classes: (i) ‘Actively-marketed’ species, either cited as cash crops by at least one respondent and/or observed on local market shelves, (ii) ‘passively-marketed’ species mentioned by key informants or in literature, but occasionally cited by farmers and rarely observed in markets, and (iii) ‘non-marketed’ species including all species not belonging to the previous classes (Bekele, 2007; Teketay et al., 2010; Molla et al., 2011; Senbeta et al. 2013).

The species richness of each category, i.e. food group, utility, edibility and marketability, were calculated using Menhinick's index (Equation 4.1) (Magurran 1988).

$$D = \frac{S}{\sqrt{\mathrm{N}}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots . Equation\ 4.1.$$

*Where D= Menhinick's index, S = number of species of a given use type/food group of a given plot, and N= total species per plot.*

Statistical analyses included the calculation of descriptive statistics for relevant biophysical and socioeconomic variables, and post-hoc analyses for subsequent testing. These included one-way ANOVA and Pearson correlation analysis. These were implemented using Minitab 17.0 (Minitab Inc. 2013) and Statistica 7.1 (StatSoft Inc. 2005) software. For correlation analysis, the nominal variables were coded (Table 4-1).

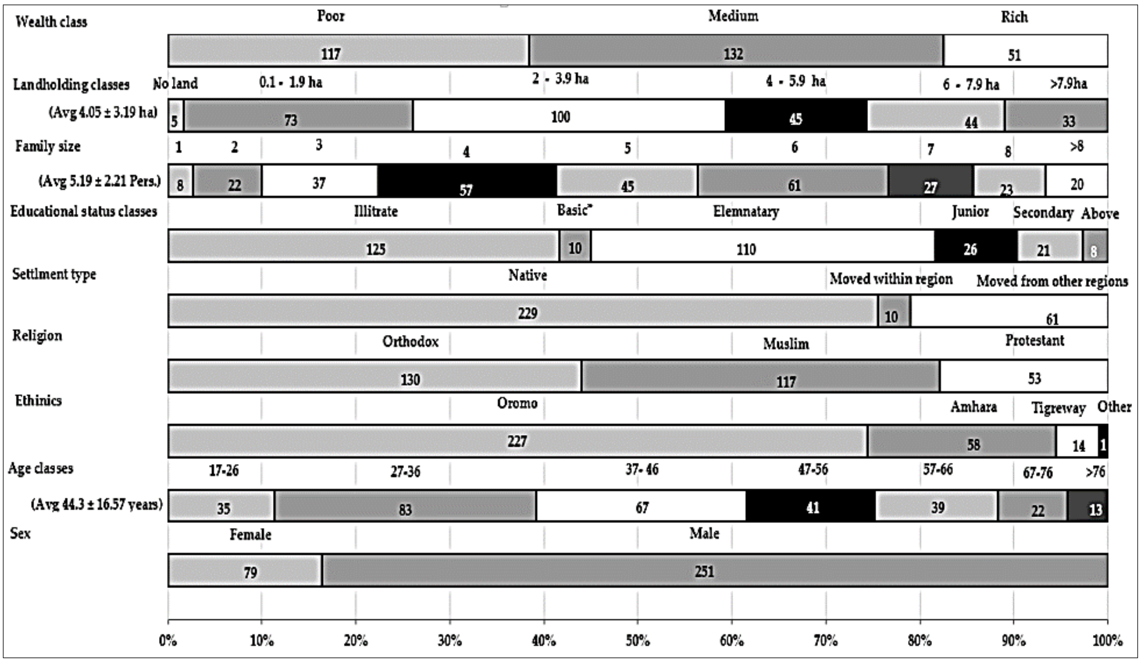
Table 4-1. Codes of nominal variables of household attributes

| Variable | Factor/type | Code |
|---|---|---|
| Gender | Male | 1 |
| | Female | 2 |
| Ethnicity | Oromo | 1 |
| | Amhara | 2 |
| | Tigreway | 3 |
| | Other | 4 |
| Settlement history | Resettled from other regions | 1 |
| | Resettled within the region | 2 |
| | Native | 3 |
| Religion | Orthodox | 1 |
| | Muslim | 2 |
| | Protestant | 3 |

## 4.3 Results

### 4.3.1 Household socioeconomic profile

Males headed the majority of the Yayu households (84%), where 44% of the households were within the medium wealth class, 17% in the rich class, and 39% in the poor class. Average family size was about 5 individuals, ranging between 4 and 6. Average age of the respondents was 44.3 years. Ethnically, 75.6% of the households belonged to the Oromo ethnic group, followed by Amhara (19.3%) and Tigreway (4.6%). The majority of the respondents were native to the area, while only 23.7% were official settlers. Illiteracy rate was very high (41.4%); here, 36.8% had attended primary school, and 18.3% school grade 6th and beyond. The average landholding size was 4.1±3.2 ha per household, (Figure 4-1).



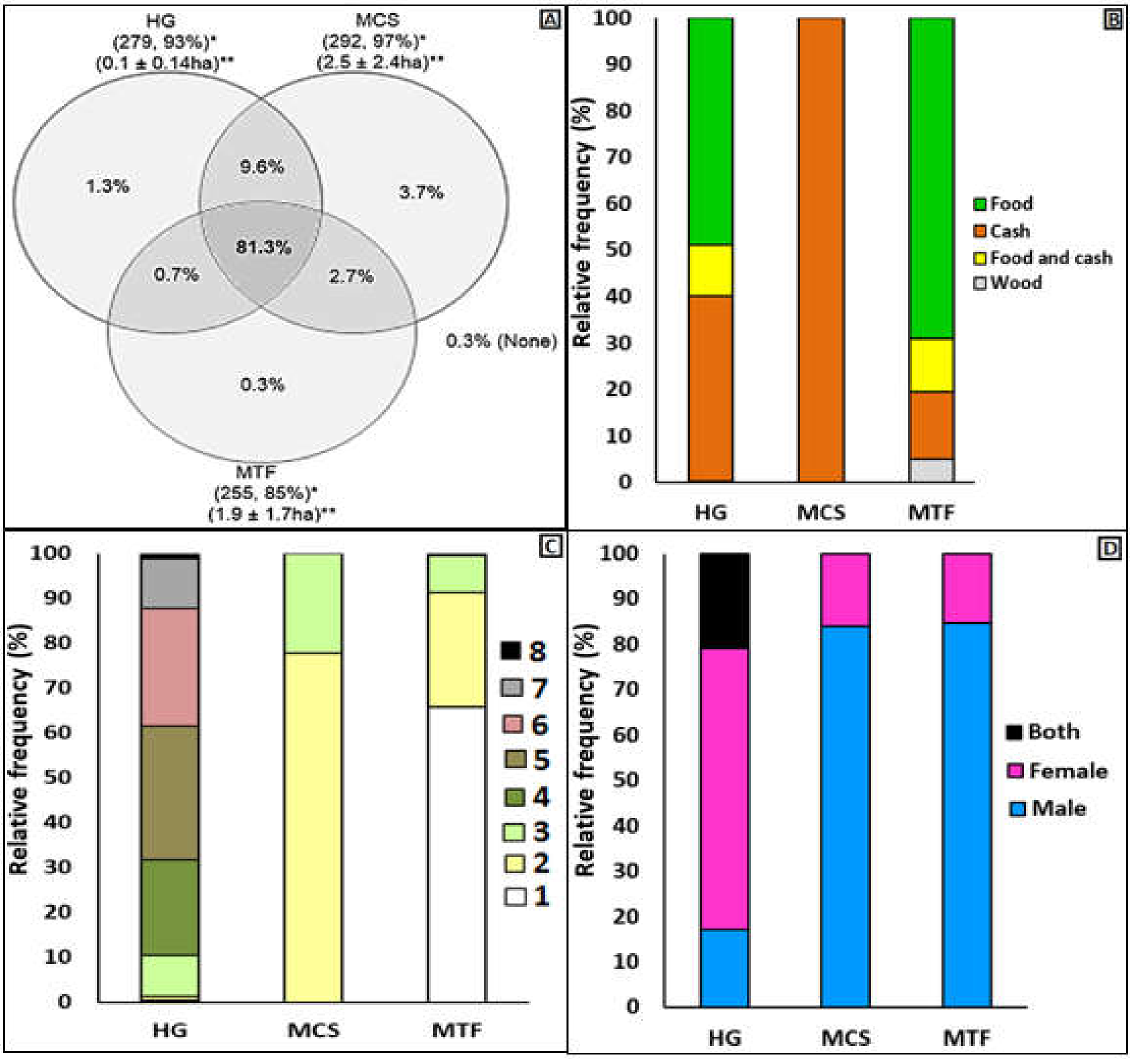
**Basic reading and writing skill acquired from non-formal school attendance, e.g. religious schooling, adult education program, etc.*

Figure 4-1. Demographic, socioeconomic and cultural attributes of sample households of Yayu.

### 4.3.2 Agroforestry practices and purposes

The three main AFP are related to three major farming land uses: homestead, coffee plot, and farmland. Based on the classification scheme of Nair (1985), practices were identified as homegarden (HG), multistorey-coffee-system (MCS), and multipurpose-trees-on-farmland (MTF). A HG is a complex multispecies production system practiced around the homestead and locally named *guwaro*. MCS is locally named *laffa bunna,* literally translated as coffee land. Although coffee cultivation is omnipresent in most land-use systems of in the region, MCS is distinguished by being primarily intended for the production of coffee, and involves various combinations of naturally grown and/or planted coffee with mostly native shade trees, and resembles a multi-strata forest. The third type MTF, locally known as *laffa qonna*, literally translated as farmland, refers to a unit of land designated for the production of annual crops but deliberately integrates perennial woody species to increase or optimize plot output.

About 81% of the respondent households practice concomitantly all three practices. MCS alone is practiced by 97% of the households, HG by 93%, and MTF by 85%. HG covers the smallest area (average 0.08 ha), and MCS the largest (2.6 ha) (Figure 4-2A). Concerning the primary purpose, MCS is used entirely for income generation, 66% of MTF is devoted to food production, in some cases also to wood and cash crop cultivation, and HG focuses on food (40%) and cash crop production (40%) (Figure 4-2B). Regarding the number of specific purposes/benefits per practice (annual crop production, fruit production, cash crop production, vegetable production, etc.), the highest was in HG (max. 8) per household, and in more than 90% of the households at least 3 specific outputs were generated. In contrast, the lowest value was found in MCS (max. 3) per household (Figure 4-2C). The main users or decision makers of MCS and MTF are dominantly males (>83%). Females dominated in HG (62%) (Figure4-2D).



**Household count, relative proportion; **size (mean±SD)*

Figure 4-2. Characteristics of predominant agroforestry practices of Yayu. 4-3A. Classification, number and size of households. 4-4B. Relative frequency of main purpose of outputs per practice. 4-5C. Relative frequency of number of benefits per practice. 4-6D. Relative frequency of the main users per gender per practice. Homegardens (HG), Multi-storey coffee systems (MCS) and Multipurpose trees on farmlands (MTF)

### 4.3.3 Floristic composition

A total 127 plant species from 47 families was identified in all three AFP. The highest number was found in HG (88), followed by MCS (65) and MTF (55). About 68.5% were perennial (tree and shrubs); herbs were absent in MCS; 69% of the species were native to the Yayu area (Figure 4-3B), and most herbs and exotic species existed in HG (Figure 4-3A). Regarding the growing niche, 48 species were found only in HG, and 24 species occurred in all three practices (Figure 4-3C). For a full list of species together with their niche, growth habit, growth cycle, and uses see Appendix 1.

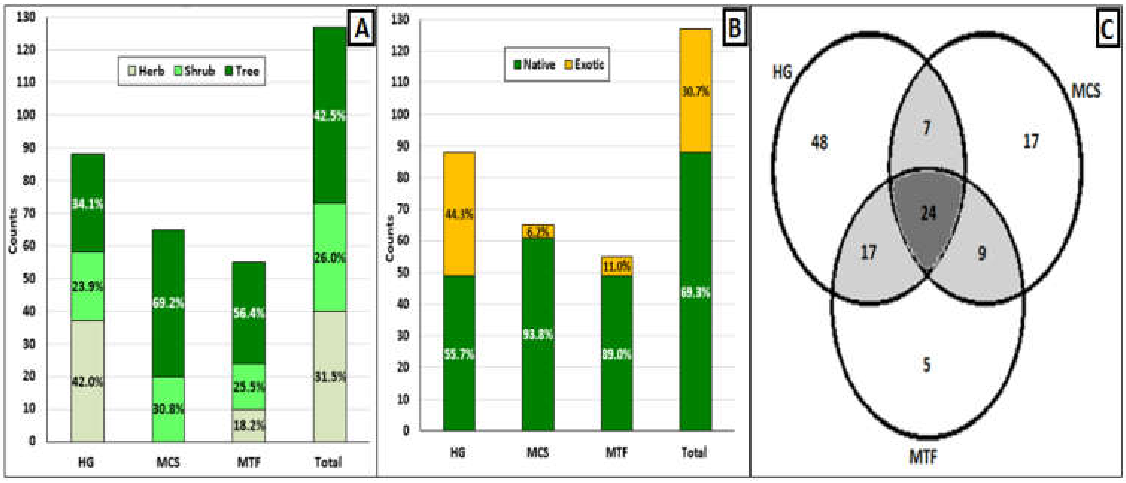


Figure 4-7. Floristic composition of local agroforestry practices of Yayu, south-western Ethiopia. 4-3A. Relative proportion per growth habit. 4-3B. Relative proportion per origin. 4-3C. Count per practice. Homegardens (HG), Multi-storey coffee systems (MCS) and Multipurpose trees on farmlands (MTF)

Concerning the frequency of occurrence of species, *Coffea arabica*, *Mangifera indica*, *Persea americana*, and *Brassica oleracea* were dominant in HG, occurring in more than 70% of the samples. Besides coffee, present in all MCS, shade tree species like *Cordia africana* and *Albizia gummifera* were present in more than 70% of the MCS samples. In contrast, MTF was dominated by the annual crop *Zea mays*, which occurred in more than 95% of the samples, followed by *Sesbania sesban* (33%), *Eragrostis tef* (31%), *Sorghum bicolor* (26.3%), and *Eucalyptus grandis* (20.8%) the remaining species were observed in less than 20% of MTF. The multipurpose tree species *Vernonia amygdalina* was the only species existing in all three practices (Figure 4-4).

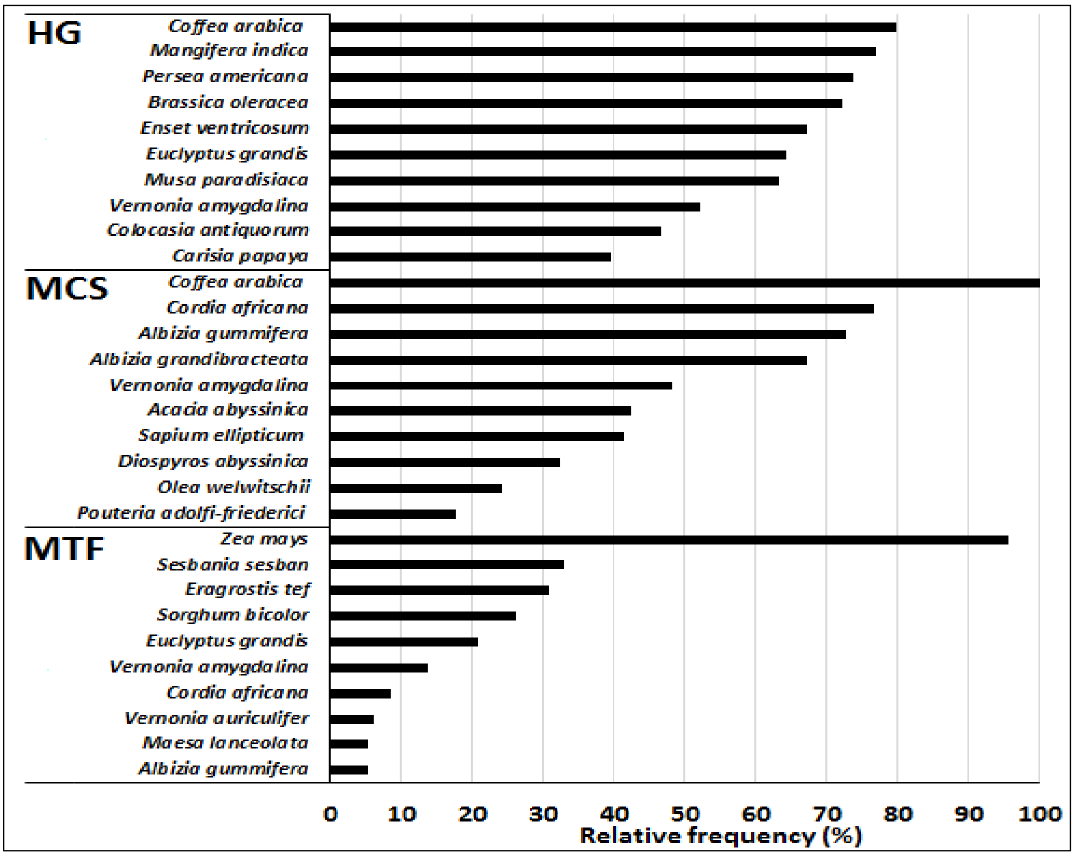
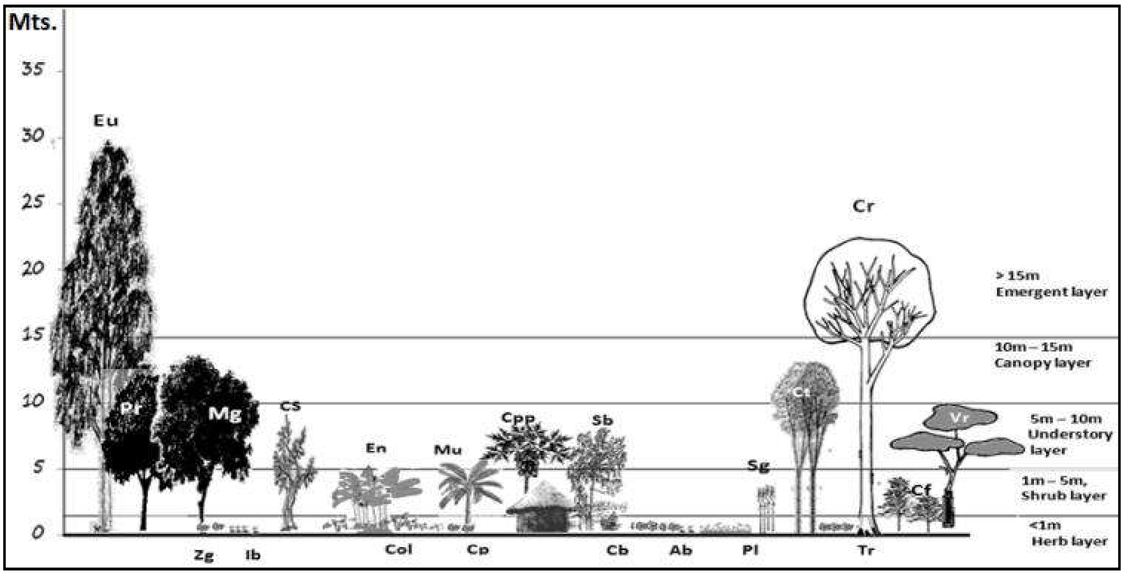


Figure 4-8. Relative frequency of the 10 most frequent species in 3 agroforestry practices in Yayu. Homegardens (HG), Multi-storey coffee systems (MCS) and Multipurpose trees on farmlands (MTF)

### 4.3.4 Structural arrangement

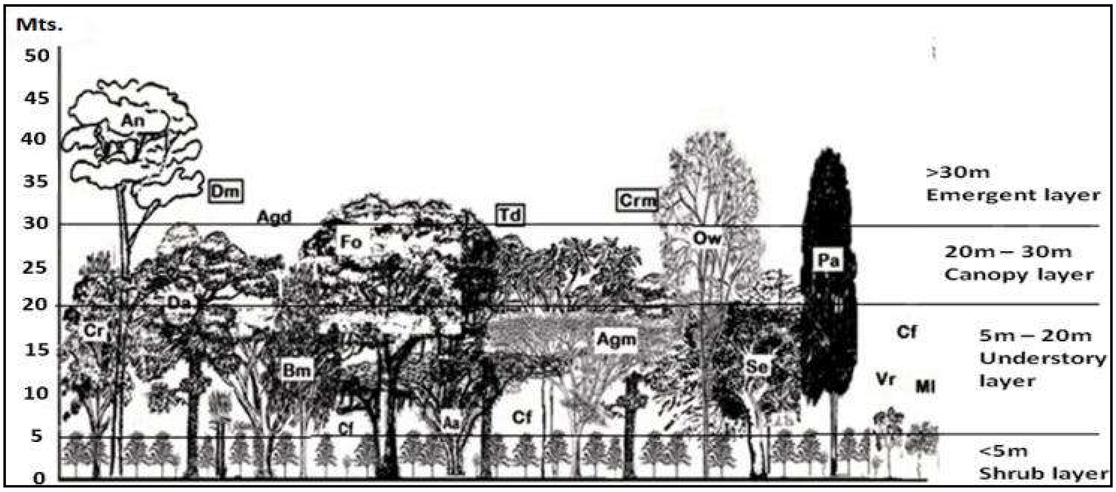
Homegardens exhibit a multi-strata vertical structure with a high diversity of species distributed with no specific spatial arrangement. The emergent layer (>15 m) is dominated by timber tree species such as *Cordia africana* and *Eucalyptus grandis*, and the canopy layer (10 m-15 m) is occupied by cash crops such as *Catha edulis* and fruit trees such as *Mangifera indica* and *Persea americana*. Multipurpose trees like *Vernonia amygdalina* and *Sesbania sesban* species mainly inhabit the understory layer (5 m-10 m). The shrub layer (1 m-5 m) is mainly covered by *Coffea arabica* and *Ensete ventricosum*. In the herbaceous layer (<1 m), species like *Brassica oleracea* and *Colocasia antiquorum* were observed; this layer scored the highest species count (35.2%) (Figure 4-5).

MCS roughly exhibits two main layers occupied by the main crop *Coffea arabica* and the shade trees. However, the shade tree species are further stratified leading to a multi-storey profile. Four layers were identified: the upper stratum (>30 m) with more than 40% species consisting of high-value timber species such as *Olea welwitschii* and *Pouteria adolfi-friederici*. The canopy layer (20-30 m) is dominated by multipurpose species such as *Cordia africana* and *Sapium ellipticum.* The understory layer (5-20m) is occupied by fewer species selected for their shading quality, e.g. *Acacia abyssinica* and *Albizia gummifera*. The shrub layer (<5 m) is almost totally dominated by *Coffea arabica* and some peripheral species like *Maesa lanceolata* and *Vernonia amygdalina* (Figure 4-6).



*Cf=Coffea arabica, Mg=Mangifera indica, Pr=Persea americana, Cb=Brassica oleracea, En=Ensete ventricosum, Eu=Eucalyptus grandis, Mu=Musa paradisiaca, Vr=Vernonia amygdalina, Col=Colocasia antiquorum, Cpp=Carica papaya, Ct=Catha edulis, Sb=Sesbania sesban, Cs=Citrus sinesis, Ib=Ipomoea batata, Zg=Zingiber officinale, Cp=Capsicum frutescens, Pl=Phaseolus lunatus, Ab=Brassica carinata, Cr=Cordia africana, Sg=Saccharum officinarum, Tr=Curcuma longa.*

Figure 4-9. Vertical profile of plant species in homegardens of Yayu



*Cf=Coffea arabica, An=Pouteria adolfi-friederici, Ow=Olea welwitschii, Da=Diosporyus mespiliformis, Dm=Dracaena fragrans, Crm=Croton macrostachyus, Ml=Maesa lanceolata, Td=Trichilia dregeana,* *Pa=Prunus africana, Fo=Ficus ovata, Se=Sapium ellipticum, Vr=Vernonia amygdalina, Agm=Albizia gummifera, Agd= Albizia grandibaracta, Cr=Cordia africana, Aa=Acacia abyssinica, Bm=Bridelia micrantha.*

Figure 4-10. Vertical profile of plant species in multistorey coffee systems of Yayu

Compared to MCS and HG, a simplified vertical profile was observed in MTF. Here, spatial overlapping was rare among species. Pruning and chopping are carried out regularly to minimize light, water, and nutrient competition; however, horizontal strata are recognizable (Figure 4-7A). The number of strata and species per stratum per agroforestry practice show an inverse trend in the number of species compared to the number of strata in HG. Most of the species in MCS and MTF are above the understorey layer (Figure 4-7B).

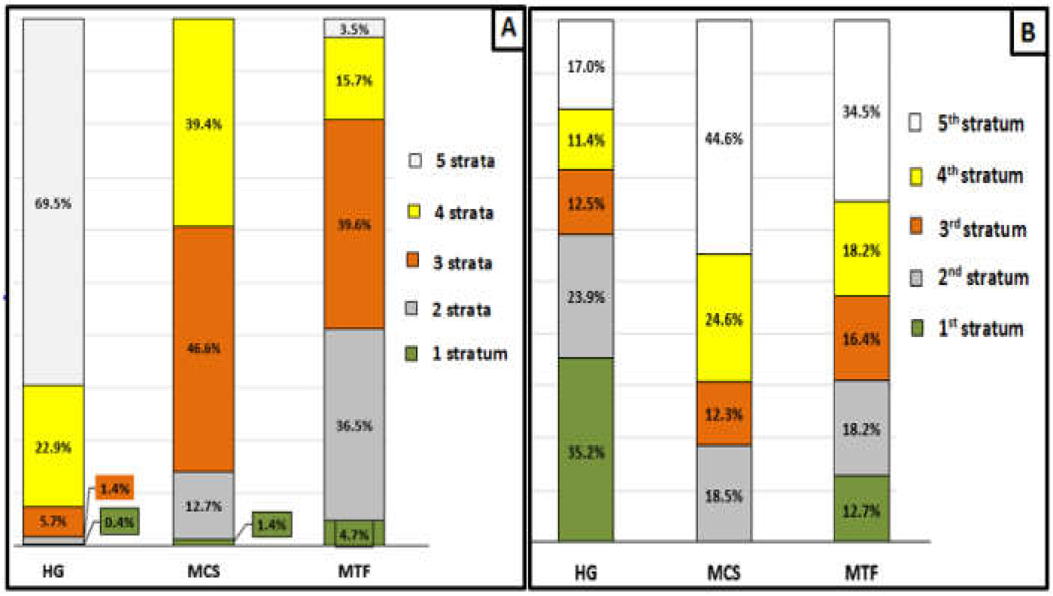


Figure 4-11. Distribution of species and strata in three agroforestry practice of Yayu. A. Number of strata per plot. B. Number of species per stratum. Homegardens (HG), Multi-storey coffee systems (MCS) and Multipurpose trees on farmlands (MTF)

### 4.3.5 Plant uses and services

In total, 10 different types of plant uses and services were observed in the three AFP (1) food, (2) spices, condiments, and other food & beverage additives, (3) stimulants, (4) fodder, (5) fuel, (6) timber, (7) non-timber tree products, (8) shade trees for coffee, (9) other services, e.g. live fences, windbreaks, demarcation, recreation and ornamental, and (10) medicine

Almost all uses were observed in all three practices. Only ‘food’ in MCS, ‘shade trees for coffee’ in MTF, and ‘spices, condiments, and other foods & beverage additives’ were missing. Regarding the species count for each use, ‘stimulants’ (2) and ‘fuel’ (52) were the two extremes. Overall, ‘food’ scored significantly high ($p<0.01$), with 7.8 species per plot in HG, whereas ‘fuel’ was the highest in MCS (7.1) and MTF (2.9). Richness per plot and count show similar trends in all uses and service categories (Table 4-1).

Table 4-2. Species count and richness of ten plant uses and service categories across agroforestry practices of the sample households of Yayu

| Use and service category | Count of total species, (%) | | | | Average number of species/HH (± SD) | | | Average richness/HH (± SD) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | All | HG | MCS | MTF | HG | MCS | MTF | HG | MCS | MTF |
| Food | 44 (34.6) | 42 (46.6) | 0 (0) | 10 (18.2) | $7.8^{A}$ (±2.9) | $0.0^{F}$ (±0.0) | $1.8^{BC}$ (±1.0) | $1.6^{A}$ (±0.5) | $0.0^{F}$ (±0.0) | $0.9^{B}$ (±0.4) |
| Spices, condiments, and other food & beverage additives | 9 (7.1) | 10 (10.2) | 0 (0) | 0 (0) | $0.6^{FG}$ (±0.9) | $0.0^{F}$ (±0.0) | $0.0^{E}$ (±0.0) | $0.1^{FG}$ (±0.2) | $0.0^{F}$ (±0.0) | $0.0^{D}$ (±0.0) |
| Stimulants | 2 (1.6) | 2 (2.3) | 2 (1.5) | 1 (1.8) | $1.2^{EFG}$ (±0.7) | $1.0^{EF}$ (±0.0) | $0.1^{DE}$ (±0.4) | $0.2^{EF}$ (±0.1) | $0.4^{E}$ (±0.1) | $0.1^{D}$ (±0.2) |
| Fodder | 41 (32.3) | 27 (29.5) | 31 (46.2) | 29 (52.7) | $2.7^{CD}$ (±2.7) | $3.6^{BC}$ (±3.4) | $2.0^{B}$ (±2.1) | $0.6^{C}$ (±0.5) | $1.3^{C}$ (±1.1) | $1.0^{B}$ (±0.8) |
| Fuel | 52 (40.9) | 27 (29.5) | 46 (69.2) | 36 (65.5) | $4.5^{B}$ (±2.1) | $7.1^{A}$ (± 3.6) | $2.9^{A}$ (±1.9) | $0.9^{B}$ (±0.4) | $2.5^{A}$ (±0.5) | $1.4^{A}$ (±0.5) |
| Timber | 34 (26.8) | 17 (18.2) | 31 (46.2) | 24 (43.6) | $1.5^{EF}$ (±1.1) | $3.4^{C}$ (±2.6) | $0.9^{CD}$ (±1.1) | $0.3^{DE}$ (±0.2) | $1.1^{C}$ (±0.6) | $0.4^{C}$ (±0.4) |
| Non-timber tree products | 10 (7.9) | 5 (4.5) | 10 (13.8) | 3 (5.5) | $0.1^{G}$ (±0.4) | $0.3^{F}$ (±0.7) | $0.1^{DE}$ (±0.3) | $0.0^{G}$ (±0.1) | $0.1^{F}$ (±0.2) | $0.01^{D}$ (±0.1) |
| Shade trees for coffee | 26 (20.5) | 20 (21.6) | 25 (36.9) | 0 (0) | $2.0^{CDE}$ (±1.7) | $4.7^{B}$ (±2.2) | $0.0^{E}$ (±0.0) | $0.4^{D}$ (±0.3) | $1.6^{B}$ (±0.5) | $0.0^{D}$ (±0.0) |
| Other services, e.g. live fences, windbreaks etc. | 18 (14.2) | 16 (17) | 15 (21.5) | 12 (21.8) | $1.9^{DE}$ (±1.2) | $2.0^{DE}$ (±1.4) | $0.9^{CD}$ (±0.9) | $0.4^{D}$ (±0.3) | $0.7^{D}$ (±0.5) | $0.5^{C}$ (±0.4) |
| Medicine | 21 (16.5) | 21 (22.7) | 9 (12.3) | 7 (12.7) | $3.1^{C}$ (±1.67) | $2.1^{D}$ (±1.1) | $0.4^{DE}$ (±0.8) | $0.6^{C}$ (±0.3) | $0.8^{D}$ (±0.3) | $0.2^{CD}$ (±0.3) |
| p-value | | | | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |

**Use and services categories of a give practices with at least one similar superscript do not significantly differ at least at α=0.05: HH = household*

#### 4.3.5.1 Food production

In all three practices, out of the 127 identified species, 80 were edible, while 55 were managed as ‘active food’, all of which except 3 species were observed in HG; on average 9 ‘active food’ species occurred in HG. The highest number of ‘potentially edible’ species were found in MCS (21), and the highest number of ‘active food’ species in HG (52). The number of ‘potentially edible’ species was highest in MCS (21) (Table 4-3). The ‘potential’ to ‘active food’ ratio reveals the highest value of untapped edible species. In MCS, both in total and at plot level the ratio reached 21:1 and 1.7:1, respectively (Table 4-2).

The ‘active food’ category was re-grouped into 10 different food groups. As expected, HG exhibited the largest variety of species of all food groups. The group ‘other fruits’ scored the highest in all parameters, whereas ‘spices, condiments and beverages’ and ‘cereals’ scored the highest species richness in MCS and MTF. The species count and richness per plot of the food groups show a significant variation ($p<0.01$) in HG and MTF (Table 4-3).

Table 4-3. Species count and richness of edible and potentially edible species

| **Edibility category/ratio** | **Total species (%)** | | | | **Average number of species/HH (± SD)** | | | **Average richness/HH (± SD)** | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **All** | **HG** | **MCS** | **MTF** | **HG** | **MCS** | **MTF** | **HG** | **MCS** | **MTF** |
| Total edible | 80 (62.9) | 63 (71.6) | 22 (33.8) | 25 (45.5) | 9.3 (± 3.6) | 2.7 (±1.4) | 2.3 (±1.3) | 2.6 (±0.6) | 0.9 (±0.3) | 1.2 (±0.4) |
| Potentially edible | 25 (19.7) | 11 (12.5) | 21 (32.3) | 14 (25.6) | 0.3 (±0.6) | 1.7 (±1.4) | 0.4 (±0.7) | 0.1 (±0.2) | 0.6 (±0.4) | 0.2 (±0.3) |
| Active food | 55 (44) | 52 (59.1) | 1 (1.5) | 11 (20.0) | 9.0 (±3.4) | 1.0 (±0.0) | 1.9 (±1.1) | 2.5 (±0.6) | 0.4 (±0.1) | 0.96 (±0.4) |
| Potential:Active (ratio) | 0.5 | 0.2 | 21.0 | 1.3 | 0.0 (±0.1) | 1.7 (±1.4) | 0.3 (±0.5) | 0.0 (±0.1) | 1.7 (±1.4) | 0.3 (±0.5) |

*HH = household*

Table 4-4. Number, percentage, frequency, richness and ANOVA of species of 10 food groups in agroforestry practices in Yayu

| **Food group** | **'Active food' species (%)** | | | | **Average number of species/HH (± SD)** | | | **Average richness /HH (± SD)** | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **All** | **HG** | **MCS** | **MTF** | **HG** | **MCS** | **MTF** | **HG** | **MCS** | **MTF** |
| Cereals | 6 (13.6) | 3 (7.1) | 0.0 (0.0) | 6 (54.5) | $0.1^{E}$ (±0.4) | 0.0 (±0.0) | $1.6^{A}$ (±0.8) | $0.1^{D}$ (±0.1) | 0.0 (±0.0) | $1.2^{A}$ (±0.3) |
| White roots and tubers | 6 (13.6) | 6 (14.3) | 0.0 (0.0) | 0 (0.0) | $1.5^{B}$ (±1.2) | 0.0 (±0.0) | 0.0 (±0.0) | $0.4^{BC}$ (±0.3) | 0.0 (±0.0) | $0.0^{B}$ (±0.0) |
| Vit-A-rich vegetables & tubers | 4 (9.1) | 4 (9.5) | 0.0 (0.0) | 0 (0.0) | $0.5^{DE}$ (±0.6) | 0.0 (±0.0) | 0.0 (±0.0) | $0.2^{D}$ (±0.2) | 0.0 (±0.0) | $0.0^{B}$ (±0.0) |
| Dark green leafy vegetables | 4 (9.1) | 4 (9.5) | 0.0 (0.0) | 0 (0.0) | $1.0^{C}$ (±0.7) | 0.0 (±0.0) | 0.0 (±0.0) | $0.3^{C}$ (±0.2) | 0.0 (±0.0) | $0.0^{B}$ (±0.0) |
| Other vegetables | 5 (11.4) | 5 (11.9) | 0.0 (0.0) | 0 (0.0) | $0.5^{DE}$ (±0.7) | 0.0 (±0.0) | 0.0 (±0.0) | $0.1^{D}$ (±0.2) | 0.0 (±0.0) | $0.0^{B}$ (±0.0) |
| Vit-A-rich fruits | 3 (6.8) | 3 (7.1) | 0.0 (0.0) | 0 (0) | $1.2^{BC}$ (±0.7 | 0.0 (±0.0) | 0.0 (±0.0) | $0.4^{C}$ (±0.2) | 0.0 (±0.0) | $0.0^{B}$ (±0.0) |
| Other fruits | 12 (27.3) | 12 (28.6) | 0.0 (0.0) | 0 (0) | $2.4^{A}$ (±1.4) | 0.0 (±0.0) | 0.0 (±0.0) | $0.8^{A}$ (±0.4) | 0.0 (±0.0) | $0.0^{B}$ (±0.0) |
| Legumes, nuts, seeds | 5 (11.4) | 5 (11.9) | 0.0 (0.0) | 4 (36.4) | $0.2^{DE}$ (±0.4) | 0.0 (±0.0) | $0.1^{B}$ (±0.4) | $0.1^{D}$ (0.1) | 0.0 (±0.0) | $0.1^{B}$ (±0.2) |
| Sweets | 1 (2.3) | 1 (2.4) | 0.0 (0.0) | 0 (0) | $0.1^{E}$ (±0.3) | 0.0 (±0.0) | 0.0 (±0.0) | $0.0^{D}$ (±0.1) | 0.0 (±0.0) | $0.0^{B}$ (±0.0) |
| Spices, condiments & beverages | 9 (20.5) | 9 (21.4) | 1.0 (1.5) | 0 (0) | $0.7^{CD}$ (±0.9) | 1.0 (±0.0) | 0.0 (±0.0) | $0.6^{B}$ (±0.3) | 1.0 (±0.0) | $0.1^{B}$ (±0.2) |
| p-value | | | | | <0.01 | | <0.01 | <0.01 | | <0.01 |

**Food groups of a give practices with at least one similar superscript do not significantly differ at least at α=0.05: HH = household*

### 4.3.5.2 Income generation

Farming in all three AFP accounts for almost 90% of the households' income (Figure 4-8A). MCS has the largest share (60%), mainly from selling *Coffea arabica*. In HG, *Coffea arabica* generates 45% of the cash, the rest is provided mainly by fruits and livestock-related activities. As MTF is mostly devoted to food production for self-consumption, the contribution to the households' income was slightly lower than in MCS and HG through the sale of cash crops such as *Catha edulis* (52%), *Eragrostis tef* and *Zea mays* (38%) (Figure 4-8 B, C and D).

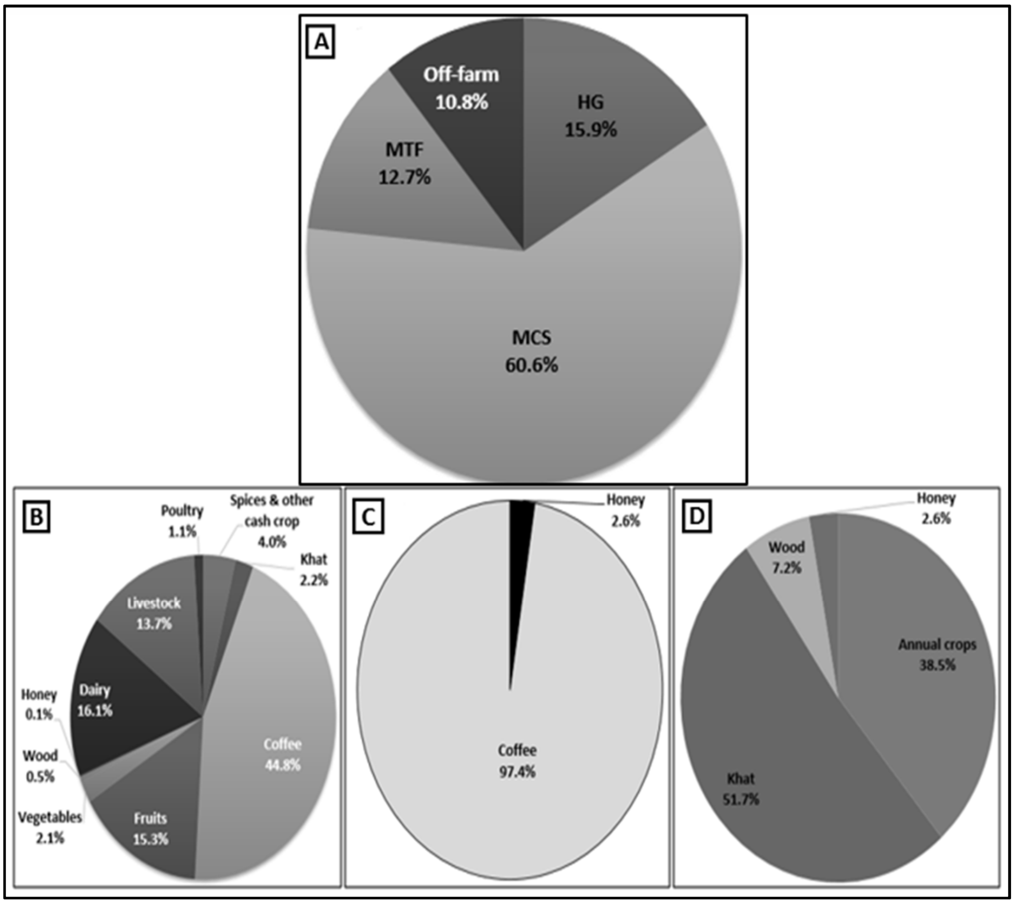


Figure 4-12 Income generation in households by (A) main agricultural and non-agricultural activities; (B) homegardens (C) multistorey-coffee-systems, and (D) multipurpose-trees-on-farmlands.

Among the 127 species identified, 50 (39.1%) were reported as 'actively-marketed' species. In terms of species composition, HG showed the highest percentage of both 'actively-marketed' and 'passively (occasionally)-marketed' species, followed by MTF scoring a four times lower species count. On the other hand, only one 'actively-marketed' species was reported in MCS (*Coffea arabica*), which has most of the 'non-marketed' species. On average, the largest number of cash crops per households was recorded in HG (7.6). Regardless of the mode of utilization, whether for self-consumption or selling, almost all households had at least one 'actively-marketed' species. The species counts and richness of all marketed species categories on MTF were found to differ significantly at $p>0.01$ (Table 4-4). The 'actively-marketed' species category was significantly different ($p<0.01$) from the 'passively-marketed' and 'non-marketed' category in all practices except in MCS (Table 4-4).

Table 4-5. Count, percentage and frequency of species of three marketability categories

| **Marketability category** | **Species count (%)** | | | | **Average number of species/HH (± SD)** | | | **Average species richness /HH (± SD)** | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **All** | **HG** | **MCS** | **MTF** | **HG** | **MCS** | **MTF** | **HG** | **MCS** | **MTF** |
| Actively-marketed species | 50 (39.4) | 47 (53.4) | 1 (1.5) | 9 (16.4) | $7.6^{A}$ (± 2.8) | $1^{B}$ (± 0.0) | $2.1^{A}$ (± 1.1) | $2.3^{A}$ (±0.6) | $0.4^{B}$ (±0.1) | $1.1^{A}$ (±0.4) |
| Passively-marketed species | 18 (14.2) | 13 (14.7) | 11 (16.9) | 10 (18.1) | $2.7^{B}$ (± 1.6) | $1.3^{B}$ (± 0.9) | $0.4^{B}$ (± 0.6) | $0.5^{B}$ (±0.3) | $0.5^{B}$(±0.3) | $0.2^{C}$ (±0.3) |
| Non-marketed species | 59 (46.5) | 28 (31.8) | 53 (81.5) | 36 (65.5) | $2.2^{B}$ (± 1.6) | $5.7^{A}$ (± 3.6) | $1.5^{C}$ (± 1.5) | $0.6^{B}$ (±0.4) | $1.9^{A}$ (±0.7) | $0.7^{B}$ (±0.5) |
| p-value | | | | | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 | <0.01 |

** Marketability categories of a give practices with at least one similar superscript do not significantly differ at least at α=0.05: HH = household*

### 4.3.6 Relation between household characteristics and agroforestry attributes

The size of all three AFP was highly correlated with wealth status of the households. Regarding the main purposes of HG, MCS, and MTF, the highest significant correlations were observed with proximity to the market, total landholding size, and altitude, respectively. With respect to the number of benefits obtained, the highest correlation was observed with HG size and the lowest with MTF. The native householder had relatively more benefits per HG plot than the resettled (Table 4-7).

Concerning the floristic composition, the number of species of all AFP plots was significantly correlated with household altitude, settlement history and total landholding size. Plot proximity to market showed significant correlation with the total number of useful species in HG and MCS. After evaluation of the species by their growth habit and origin, proximity to market was still significantly correlated with the number of herbaceous, shrub and tree species. The number of exotic species showed a significant rise with proximity to markets in all practices except MCS. Furthermore, proximity to market, wealth status, and size of MCS plots were significantly correlated with the number of strata in all AFP. Native households had a higher number of shrubs per HG, trees per MCS and storeys per MCS than resettled households (Table 4-6).

Table 4-6. Pearson correlation coefficients between features of agroforestry practices and household characteristics in Yayu

| **Feature** | **AFP** | **Altitude** | **Proximity to market** | **Proximity to forest** | **Gender$^{\beta}$** | **Age** | **Ethnicity$^{\beta}$** | **Settlement history$^{\beta}$** | **Education level** | **Religion$^{\beta}$** | **Family size** | **Wealth status** | **Total land size** | **HG size** | **MCS size** | **MTF size** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plot size | HG | -0.19$^{**}$ | -0.16$^{**}$ | -0.01 | 0.19$^{**}$ | -0.28$^{**}$ | -0.09 | -0.05 | 0.12* | -0.03 | 0.26$^{**}$ | 0.73$^{**}$ | 0.57$^{**}$ | - | 0.45$^{**}$ | 0.45$^{**}$ |
|  | MCS | -0.25$^{**}$ | -0.29$^{**}$ | 0.16$^{*}$ | -0.15* | -0.21$^{**}$ | -0.08 | 0.03 | 0.11 | 0.0 | 0.29$^{**}$ | 0.37$^{**}$ | 0.82$^{**}$ | 0.45$^{**}$ | - | 0.24$^{**}$ |
|  | MTF | 0.16$^{**}$ | 0.36$^{**}$ | 0.13$^{*}$ | -0.21$^{**}$ | -0.13$^{*}$ | 0.08 | -0.12$^{*}$ | -0.08 | -0.09 | 0.17$^{**}$ | 0.60$^{**}$ | 0.64$^{**}$ | 0.45$^{**}$ | 0.24$^{**}$ | - |
| Type of main purpose | HG | -0.16$^{**}$ | -0.18$^{**}$ | -0.03 | -0.17$^{**}$ | 0.11 | -0.17 | 0.13$^{*}$ | -0.01 | 0.11 | 0.15$^{*}$ | 0.14$^{*}$ | 0.16$^{**}$ | 0.28$^{**}$ | 0.14$^{*}$ | 0.11 |
|  | MCS | -0.04 | -0.05 | 0.01 | -0.04 | 0.04 | 0.05 | -0.01 | -0.04 | -0.03 | 0.04 | 0.14$^{*}$ | 0.18$^{**}$ | 0.07 | 0.17$^{**}$ | 0.09 |
|  | MTF | -0.25$^{**}$ | -0.22$^{**}$ | 0.06 | 0.03 | 0.14$^{*}$ | 0.01 | -0.01 | -0.08 | 0.03 | 0.03 | 0.14$^{*}$ | 0.16$^{**}$ | 0.15$^{**}$ | 0.16$^{**}$ | 0.07 |
| Number of benefits | HG | -0.24$^{**}$ | -0.19$^{**}$ | -0.06 | -0.12$^{*}$ | 0.15$^{*}$ | -0.2$^{**}$ | 0.17$^{**}$ | -0.08 | 0.04 | 0.22$^{**}$ | 0.23$^{**}$ | 0.22$^{**}$ | 0.51$^{**}$ | 0.23$^{**}$ | 0.10 |
|  | MCS | -0.15$^{**}$ | -0.15 | 0.09 | -0.17$^{**}$ | 0.05 | -0.02 | 0.04 | 0.01 | 0.06 | 0.20$^{**}$ | 0.3$^{**}$ | 0.34$^{**}$ | 0.25$^{**}$ | 0.34$^{**}$ | 0.15$^{**}$ |
|  | MTF | -0.31$^{**}$ | -0.30$^{**}$ | -0.02 | -0.08 | 0.17$^{**}$ | -0.14 | 0.11 | -0.03 | 0.06 | 0.15$^{*}$ | 0.23$^{**}$ | 0.24$^{**}$ | 0.28$^{**}$ | 0.22$^{**}$ | 0.14$^{*}$ |

**significant correlation at p<0.05; ** significant correlation at p<0.01; $^{\beta}$ nominal variables; wealth status '1' = poor and '3' = rich; HH = household*

Table 4-7. Pearson correlation analysis of floristic composition and structural variables of agroforestry practices and household characteristics in Yayu

| Variable | AFP | Altitude | Proximity to market | Proximity to forest | Gender$^{\beta}$ | Age | Ethnicity$^{\beta}$ | Settlement history$^{\beta}$ | Education level | Religion$^{\beta}$ | Family size | Wealth status | Total land size | HG size | MCS size | MTF size |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total no. of species | HG | -0.33$^{**}$ | -0.30$^{**}$ | -0.12 | 0.01 | 0.08 | -0.15$^{*}$ | 0.16$^{**}$ | 0.01 | 0.15$^{*}$ | 0.12$^{*}$ | 0.09 | 0.13$^{*}$ | 0.17$^{**}$ | 0.25$^{**}$ | -0.12 |
| | MCS | -0.27$^{**}$ | -0.33$^{**}$ | 0.08 | -0.08 | 0.06 | -0.16$^{**}$ | 0.18$^{**}$ | 0.10 | 0.06 | 0.17$^{**}$ | 0.14$^{*}$ | 0.25$^{**}$ | 0.11 | 0.33$^{**}$ | -0.01 |
| | MTF | -0.13$^{*}$ | -0.12 | 0.09 | -0.10 | 0.05 | -0.14$^{*}$ | 0.13$^{*}$ | 0.08 | 0.10 | 0.22$^{**}$ | 0.09 | 0.17$^{**}$ | 0.15$^{*}$ | 0.20$^{**}$ | 0.03 |
| No. of Herbs | HG | -0.20$^{**}$ | -0.21$^{**}$ | -0.02 | 0.12$^{*}$ | 0.07 | -0.06 | 0.08 | 0.00 | 0.09 | 0.02 | -0.10 | -0.01 | -0.06 | 0.11 | -0.19$^{**}$ |
| | MTF | 0.24$^{**}$ | 0.31$^{**}$ | -0.14$^{*}$ | -0.20$^{**}$ | -0.01 | -0.10 | 0.05 | 0.05 | 0.05 | 0.13$^{*}$ | 0.155$^{*}$ | 0.23$^{**}$ | 0.10 | 0.07 | 0.34$^{**}$ |
| No. of Shrubs | HG | -0.30$^{**}$ | -0.23$^{**}$ | -0.11 | -0.04 | 0.11 | -0.18$^{**}$ | 0.18$^{**}$ | 0.01 | 0.15$^{*}$ | 0.12 | 0.20$^{**}$ | 0.20$^{**}$ | 0.29$^{**}$ | 0.26$^{**}$ | 0.01 |
| | MCS | -0.18$^{**}$ | -0.22$^{**}$ | 0.10 | 0.00 | 0.04 | -0.07 | 0.10 | 0.00 | 0.11 | 0.19$^{**}$ | 0.12 | 0.12$^{*}$ | 0.15$^{**}$ | 0.17$^{**}$ | -0.01 |
| | MTF | -0.18$^{**}$ | -0.21$^{**}$ | 0.15 | -0.04 | 0.01 | -0.07 | 0.07 | 0.04 | 0.06 | 0.20$^{**}$ | 0.13$^{*}$ | 0.16$^{**}$ | 0.17$^{**}$ | 0.24$^{**}$ | -0.04 |
| No. of Trees | HG | -0.23$^{**}$ | -0.20$^{**}$ | -0.13$^{*}$ | -0.09 | -0.02 | -0.09 | 0.09 | 0.01 | 0.08 | 0.146$^{*}$ | 0.14$^{*}$ | 0.12$^{*}$ | 0.18$^{**}$ | 0.19$^{**}$ | -0.04 |
| | MCS | -0.26$^{**}$ | -0.32$^{**}$ | 0.06 | -0.10 | 0.05 | -0.16$^{**}$ | 0.17$^{**}$ | 0.12 | 0.04 | 0.13$^{*}$ | 0.13$^{*}$ | 0.25$^{**}$ | 0.08 | 0.33$^{**}$ | -0.01 |
| | MTF | -0.25$^{**}$ | -0.26$^{**}$ | 0.14$^{*}$ | 0.01 | 0.06 | -0.10 | 0.11 | 0.06 | 0.08 | 0.13$^{*}$ | -0.04 | 0.01 | 0.05 | 0.12 | -0.15$^{*}$ |
| No. of Native species | HG | -0.17$^{**}$ | -0.09 | -0.18$^{**}$ | -0.02 | 0.04 | -0.30$^{**}$ | 0.27$^{**}$ | -0.01 | 0.18$^{**}$ | 0.07 | 0.09 | 0.10 | 0.17$^{**}$ | 0.17$^{**}$ | -0.05 |
| | MCS | -0.27$^{**}$ | -0.33$^{**}$ | 0.08 | -0.08 | 0.05 | -0.16$^{**}$ | 0.18$^{**}$ | 0.10 | 0.06 | 0.17$^{**}$ | 0.14$^{*}$ | 0.24$^{**}$ | 0.11$^{*}$ | 0.32$^{**}$ | -0.01 |
| | MTF | -0.07 | -0.07 | 0.11 | -0.08 | 0.06 | -0.14$^{*}$ | 0.12 | 0.08 | 0.13$^{*}$ | 0.21$^{**}$ | 0.07 | 0.15$^{*}$ | 0.12 | 0.18$^{**}$ | 0.02 |
| No. of Exotic species | HG | -0.36$^{**}$ | -0.38$^{**}$ | -0.02 | 0.03 | 0.08 | 0.05 | 0.00 | 0.02 | 0.06 | 0.12$^{*}$ | 0.06 | 0.11 | 0.11 | 0.23$^{**}$ | -0.13$^{*}$ |
| | MCS | -0.08 | -0.09 | 0.07 | 0.02 | 0.07 | 0.00 | 0.03 | 0.05 | 0.02 | 0.07 | 0.08 | 0.14$^{*}$ | 0.05 | 0.23$^{**}$ | -0.06 |
| | MTF | -0.21$^{**}$ | -0.19$^{**}$ | -0.04 | -0.10 | -0.03 | -0.04 | 0.04 | 0.01 | -0.05 | 0.08 | 0.10 | 0.10 | 0.12 | 0.11 | 0.04 |
| No. of Strata | HG | -0.14$^{*}$ | -0.14$^{*}$ | -0.11 | -0.11 | 0.03 | -0.13$^{*}$ | 0.10 | 0.02 | 0.14$^{*}$ | 0.11 | 0.16$^{**}$ | 0.13$^{**}$ | 0.12$^{*}$ | 0.18$^{**}$ | 0.00 |
| | MCS | -0.28$^{**}$ | -0.25$^{**}$ | -0.02 | -0.16$^{**}$ | -0.02 | -0.09 | 0.13$^{*}$ | 0.133$^{*}$ | -0.06 | 0.12$^{*}$ | 0.15$^{**}$ | 0.14$^{*}$ | 0.05 | 0.19$^{**}$ | 0.01 |
| | MTF | -0.11 | -0.14$^{*}$ | 0.07 | -0.17$^{**}$ | 0.07 | -0.17$^{**}$ | 0.14$^{*}$ | 0.06 | 0.11 | 0.23$^{**}$ | 0.13$^{*}$ | 0.25$^{**}$ | 0.17$^{**}$ | 0.30$^{**}$ | 0.04 |

**significant correlation at $p<0.05$; ** significant correlation at $p<0.01$; β nominal variables; wealth status '1' = poor and '3' =rich; HH = household*

The Pearson correlation analysis revealed that in HG, species richness of food plants was highly correlated with market proximity (Table 4-8). The richness of fodder species in all AFP was highly correlated with family size, HG size, wealth status and gender. Fuel acquisition, species richness in MCS and MTF were also correlated with household altitude and proximity to the market. Again, the natives had a higher number of ‘food’, ‘stimulant’ and ‘medicinal’ species in their HG.

Regarding species edibility potential, species richness of ‘total edible’ species in HG showed significant correlation with proximity to market, altitude, and the size of MTF and MCS plots. Similarly, in MTF were also correlated with altitude, and proximity to market. The richness of ‘potentially edible’ species in HG decreased with distance from forest resources. In HG and MCS, the richness of ‘active food’ species was strongly and negatively correlated with proximity to markets, whereas in MTF, the richness of ‘active food’ species correlated with size of the plots (Table 4-9).

Table 4-8. Pearson correlation coefficients between species richness and service categories of agroforestry practices vs characteristics of households in Yayu

| Category | AFP | Altitude | Proximity to market | Proximity to forest | Gender$^{\beta}$ | Age | Ethnicity$^{\beta}$ | Settlement history$^{\beta}$ | Education level | Religion$^{\beta}$ | Family size | Wealth status | Total land size | HG size | MCS size | MTF size |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Food | HG | $-0.26^{**}$ | $-0.3^{**}$ | -0.02 | 0.08 | $0.13^{*}$ | $-0.12^{*}$ | $0.15^{*}$ | 0.05 | 0.09 | 0.04 | -0.04 | 0.04 | -0.05 | $0.13^{*}$ | $-0.17^{**}$ |
|  | MCS | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
|  | MTF | $0.32^{**}$ | $0.38^{**}$ | $-0.16^{*}$ | $-0.19^{**}$ | -0.02 | -0.08 | 0.04 | 0.04 | 0.00 | 0.07 | $0.14^{*}$ | $0.17^{**}$ | 0.11 | 0.03 | $0.33^{**}$ |
| Spices, condiments, and other food & beverage additives | HG | 0.07 | $0.13^{*}$ | -0.01 | 0.09 | -0.03 | 0.11 | $-0.17^{**}$ | 0.00 | -0.05 | -0.02 | -0.04 | -0.01 | -0.06 | -0.07 | 0.00 |
|  | MCS | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
|  | MTF | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Stimulants | HG | $-0.29^{**}$ | $-0.26^{**}$ | 0.09 | -0.10 | -0.02 | $-0.2^{**}$ | $0.21^{**}$ | 0.06 | 0.11 | 0.04 | 0.15* | 0.06 | 0.14* | 0.11 | -0.06 |
|  | MCS | $0.29^{**}$ | $0.35^{**}$ | -0.09 | 0.13* | -0.05 | $0.15^{**}$ | $-0.18^{**}$ | $-0.12^{*}$ | -0.06 | $-0.18^{**}$ | -0.11 | $-0.15^{**}$ | -0.11 | $-0.21^{**}$ | 0.02 |
|  | MTF | $-0.34^{**}$ | $-0.34^{**}$ | 0.12 | -0.02 | 0.10 | -0.08 | 0.11 | -0.05 | $0.13^{*}$ | $0.13^{*}$ | 0.12 | $0.22^{**}$ | $0.18^{**}$ | $0.29^{**}$ | -0.10 |
| Fodder | HG | 0.02 | 0.06 | $-0.13^{*}$ | $-0.21^{**}$ | 0.00 | -0.06 | 0.05 | -0.01 | 0.01 | $0.16^{**}$ | $0.29^{**}$ | $0.14^{*}$ | $0.37^{**}$ | 0.10 | 0.09 |
|  | MCS | 0.01 | 0.05 | -0.04 | $-0.22^{**}$ | 0.05 | 0.03 | -0.08 | -0.06 | -0.07 | $0.22^{**}$ | $0.33^{**}$ | $0.15^{**}$ | $0.36^{**}$ | 0.06 | $0.14^{*}$ |
|  | MTF | 0.03 | 0.04 | -0.02 | $-0.22^{**}$ | 0.06 | 0.04 | -0.06 | -0.03 | -0.03 | $0.23^{**}$ | $0.33^{**}$ | $0.2^{**}$ | $0.33^{**}$ | $0.13^{*}$ | 0.12 |
| Fuel | HG | -0.05 | 0.01 | $-0.14^{*}$ | $-0.12^{*}$ | -0.02 | -0.11 | 0.10 | 0.04 | 0.06 | 0.12 | $0.16^{**}$ | 0.09 | $0.17^{**}$ | 0.09 | 0.00 |
|  | MCS | $-0.22^{**}$ | $-0.26^{**}$ | 0.08 | -0.07 | 0.04 | $-0.15^{*}$ | $0.16^{**}$ | 0.11 | 0.08 | $0.12^{*}$ | 0.06 | $0.13^{*}$ | 0.05 | $0.20^{**}$ | -0.03 |
|  | MTF | $-0.32^{**}$ | $-0.33^{**}$ | $0.13^{*}$ | 0.03 | 0.04 | -0.07 | 0.08 | -0.03 | 0.00 | 0.10 | 0.01 | -0.02 | 0.02 | 0.08 | $-0.22^{**}$ |
| Timber | HG | -0.01 | 0.02 | -0.10 | $-0.12^{*}$ | 0.03 | -0.03 | 0.06 | 0.00 | 0.03 | $0.16^{**}$ | $0.18^{**}$ | 0.11 | $0.15^{*}$ | 0.08 | 0.06 |
|  | MCS | $-0.28^{**}$ | $-0.34^{**}$ | 0.03 | -0.10 | 0.01 | -0.09 | 0.11 | $0.13^{*}$ | -0.02 | 0.09 | 0.11 | $0.15^{*}$ | 0.03 | $0.21^{**}$ | -0.05 |
|  | MTF | $-0.28^{**}$ | $-0.33^{**}$ | 0.10 | -0.04 | -0.04 | -0.09 | 0.12 | 0.10 | 0.02 | 0.04 | -0.10 | -0.11 | -0.09 | 0.00 | $-0.20^{**}$ |

| **Category** | **AFP** | **Altitude** | **Proximity to market** | **Proximity to forest** | **Gender$^{\beta}$** | **Age** | **Ethnicity$^{\beta}$** | **Settlement history$^{\beta}$** | **Education level** | **Religion$^{\beta}$** | **Family size** | **Wealth status** | **Total land size** | **HG size** | **MCS size** | **MTF size** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Non-timber tree products | HG | 0.09 | 0.06 | -0.03 | 0.01 | -0.04 | 0.11 | -0.07 | 0.09 | 0.02 | 0.03 | -0.06 | -0.08 | -0.04 | -0.06 | -0.12 |
| | MCS | -0.01 | 0.03 | 0.11 | -0.13$^{*}$ | -0.02 | -0.04 | 0.03 | 0.07 | 0.09 | 0.05 | 0.07 | 0.12$^{*}$ | 0.05 | 0.14* | 0.08 |
| | MTF | 0.03 | 0.03 | 0.04 | -0.03 | -0.11 | -0.01 | 0.00 | 0.03 | 0.08 | 0.08 | -0.12 | -0.08 | -0.17$^{**}$ | -0.05 | -0.10 |
| Shade trees for coffee | HG | -0.11 | -0.07 | -0.17$^{**}$ | -0.10 | 0.01 | -0.05 | 0.06 | -0.01 | 0.04 | 0.14$^{*}$ | 0.13$^{*}$ | 0.07 | 0.18$^{**}$ | 0.06 | -0.01 |
| | MCS | -0.16$^{**}$ | -0.20$^{**}$ | 0.10 | -0.16$^{**}$ | 0.05 | -0.06 | 0.07 | 0.10 | -0.01 | 0.18$^{**}$ | 0.07 | 0.08 | 0.06 | 0.10 | -0.02 |
| | MTF | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| Live-fence, ornamental and other service | HG | -0.01 | 0.11 | 0.02 | -0.11 | -0.03 | 0.04 | 0.01 | 0.01 | 0.10 | 0.14$^{*}$ | 0.23$^{**}$ | 0.17$^{**}$ | 0.18$^{**}$ | 0.09 | 0.14$^{*}$ |
| | MCS | -0.24$^{**}$ | -0.22$^{**}$ | 0.11 | -0.08 | -0.03 | 0.07 | -0.08 | 0.03 | -0.04 | 0.16$^{**}$ | 0.14$^{*}$ | 0.10 | 0.12$^{*}$ | 0.15$^{**}$ | -0.05 |
| | MTF | -0.20$^{**}$ | -0.15$^{*}$ | 0.04 | -0.01 | -0.01 | 0.01 | -0.01 | -0.07 | 0.02 | 0.02 | 0.09 | 0.08 | 0.10 | 0.10 | -0.04 |
| Medicine | HG | -0.19$^{**}$ | -0.09 | -0.10 | -0.07 | 0.07 | -0.16$^{**}$ | 0.14$^{*}$ | 0.02 | 0.18$^{**}$ | 0.07 | 0.14$^{*}$ | 0.12$^{*}$ | 0.15$^{*}$ | 0.13$^{*}$ | 0.01 |
| | MCS | 0.21$^{**}$ | 0.24$^{**}$ | 0.13$^{*}$ | 0.00 | 0.04 | 0.08 | -0.06 | -0.13$^{*}$ | 0.04 | 0.05 | 0.02 | 0.00 | -0.02 | -0.07 | 0.07 |
| | MTF | -0.21$^{**}$ | -0.20$^{**}$ | 0.10 | 0.05 | 0.03 | -0.06 | 0.06 | -0.07 | 0.11 | 0.10 | 0.03 | 0.08 | 0.07 | 0.12 | -0.13$^{*}$ |

**significant correlation at p<0.05; ** significant correlation at p<0.01; β nominal variables; wealth status 1 is for poor and 3 is for rich; HH = household*

Table 4-9. Pearson correlation coefficients between species richness of edibility categories of agroforestry practices vs the characteristics of households in Yayu

| Category | AFP | Altitude | Proximity to market | Proximity to forest | Gender$^{\beta}$ | Age | Ethnicity$^{\beta}$ | Settlement history$^{\beta}$ | Education level | Religion$^{\beta}$ | Family size | Wealth status | Total land size | HG size | MCS size | MTF size |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Edible species total | HG | -0.35$^{**}$ | -0.36$^{**}$ | -0.01 | 0.09 | 0.11 | -0.10 | 0.11 | 0.00 | 0.09 | 0.05 | -0.02 | 0.06 | -0.01 | 0.17$^{**}$ | -0.20$^{**}$ |
| | MCS | -0.04 | -0.08 | 0.02 | 0.06 | -0.07 | -0.03 | 0.05 | -0.07 | 0.02 | 0.07 | 0.00 | 0.06 | -0.06 | 0.13$^{*}$ | -0.01 |
| | MTF | 0.15$^{*}$ | 0.13$^{*}$ | -0.01 | -0.13$^{*}$ | 0.02 | -0.15$^{*}$ | 0.14$^{*}$ | 0.12 | 0.11 | 0.11 | 0.02 | 0.11 | 0.02 | 0.07 | 0.13$^{*}$ |
| Potentially edible species | HG | -0.03 | 0.05 | -0.17$^{**}$ | -0.10 | 0.03 | 0.02 | -0.01 | 0.03 | -0.03 | 0.14$^{*}$ | 0.13 | 0.16$^{**}$ | 0.14$^{*}$ | 0.14$^{*}$ | 0.04 |
| | MCS | -0.12$^{*}$ | -0.17$^{**}$ | 0.04 | 0.01 | -0.05 | -0.08 | 0.10 | -0.02 | 0.03 | 0.12$^{*}$ | 0.03 | 0.10 | -0.02 | 0.17$^{**}$ | -0.02 |
| | MTF | -0.03 | -0.13$^{*}$ | 0.14$^{*}$ | 0.07 | -0.01 | -0.07 | 0.09 | 0.15$^{*}$ | 0.08 | 0.00 | -0.21$^{**}$ | -0.17$^{**}$ | -0.21$^{**}$ | -0.08 | -0.2$^{**}$ |
| Active food species | HG | -0.34$^{**}$ | -0.37$^{**}$ | 0.03 | 0.11 | 0.11 | -0.11 | 0.11 | -0.01 | 0.10 | 0.02 | -0.06 | 0.02 | -0.05 | 0.13$^{*}$ | -0.21$^{**}$ |
| | MCS | 0.29$^{**}$ | 0.35$^{**}$ | -0.09 | 0.13$^{*}$ | -0.05 | 0.15$^{**}$ | -0.18$^{**}$ | -0.12$^{*}$ | -0.06 | -0.18 | -0.11 | -0.15$^{**}$ | -0.11 | -0.21$^{**}$ | 0.02 |
| | MTF | 0.19$^{**}$ | 0.25$^{**}$ | -0.12 | -0.2$^{**}$ | 0.03 | -0.12 | 0.09 | 0.02 | 0.07 | 0.12 | 0.19$^{**}$ | 0.26$^{**}$ | 0.18$^{**}$ | 0.15$^{*}$ | 0.30$^{**}$ |

**significant correlation at p<0.05; ** significant correlation at p<0.01; β nominal variables; wealth status 1 is for poor and 3 is for rich; HH = household*

The ‘active food’ category was further classified into 10 food groups and subjected to correlation analysis with household characteristics. The species richness of the ‘cereal’ food group in HG and MTF had the strongest correlation with size and altitude. Root and tuber richness in HG was mainly correlated with settlement history and ethnicity of the household. Similarly, richness of vitamin-A-rich vegetable species in HG was mainly correlated with settlement history and ethnicity. The vitamin-A-rich dark vegetables and fruits showed the highest correlation with proximity to market and altitude, respectively. The native households had HG richer in tubers and root crops and vitamin-A rich dark vegetables. Regarding legume species richness of the HG and MTF plots, the highest correlation was detected with MTF size and proximity to market (Table 4-10).

Furthermore, gender also had a significant relation with the species richness of some food groups. For example, female-headed households had HG richer in tubers and root crops than male-headed. However, in the MTF plots of female-headed households with cereals and legumes, species richness was poorer than in male-headed households (Table 4-10).

Considering the marketability attributes, each practice showed similar correlations, i.e. ‘actively-marketed’ species in HG and MCS with household proximity to markets. In the MTF plots, gender also had a significant correlation with the richness of ‘actively-marketed’ species. Furthermore, the resettled households had MCS plots richer in ‘actively-marketed’ species than the native households (Table 4-11).

Table 4-10. Pearson correlation analysis among species richness of edibility and marketability categories of agroforestry practices and household characteristics of Yayu

| **Food group** | **AFP** | **Altitude** | **Proximity to market** | **Proximity to forest** | **Gender$^{\beta}$** | **Age** | **Ethnicity$^{\beta}$** | **Settlement history$^{\beta}$** | **Education level** | **Religion$^{\beta}$** | **Family size** | **Wealth status** | **Total land size** | **HG size** | **MCS size** | **MTF size** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Cereals | HG | 0.00 | -0.04 | -0.09 | 0.08 | -0.12 | -0.08 | 0.11 | 0.14$^{*}$ | 0.07 | -0.05 | -0.18$^{**}$ | -0.25$^{**}$ | -0.13$^{*}$ | -0.13$^{*}$ | -0.47$^{**}$ |
| | MTF | 0.28$^{**}$ | 0.27$^{**}$ | -0.12 | -0.14$^{*}$ | 0.02 | -0.07 | 0.04 | 0.07 | 0.052 | 0.14$^{*}$ | 0.16$^{**}$ | 0.15$^{*}$ | 0.09 | 0.05 | 0.27$^{**}$ |
| Roots &tubers | HG | -0.08 | -0.14$^{*}$ | -0.11 | 0.15$^{*}$ | 0.19$^{**}$ | -0.34$^{**}$ | 0.40$^{**}$ | -0.05 | 0.16$^{**}$ | 0.02 | -0.07 | -0.01 | -0.02 | 0.06 | -0.03 |
| Legumes & nuts | HG | -0.01 | -0.05 | 0.07 | 0.06 | -0.03 | -0.08 | 0.01 | 0.08 | 0.08 | -0.09 | -0.21$^{**}$ | -0.21$^{**}$ | -0.13$^{*}$ | -0.12 | -0.27$^{**}$ |
| | MTF | 0.14$^{*}$ | 0.25$^{**}$ | -0.11 | -0.15$^{*}$ | -0.09 | -0.07 | 0.04 | 0.03 | -0.015 | -0.05 | 0.10 | 0.06 | 0.04 | -0.03 | 0.18$^{**}$ |
| Vit.-A-rich vegetables | HG | -0.01 | 0.10 | 0.08 | -0.02 | 0.05 | 0.20$^{**}$ | -0.19$^{**}$ | -0.05 | -0.10 | 0.03 | 0.03 | 0.05 | 0.01 | -0.03 | 0.07 |
| Vit.-A-rich dark green leafy vegetables | HG | 0.13$^{*}$ | 0.19$^{**}$ | -0.05 | 0.02 | -0.09 | -0.12$^{*}$ | 0.13$^{*}$ | 0.01 | 0.04 | -0.03 | -0.13$^{*}$ | -0.09 | -0.14$^{*}$ | -0.11 | -0.05 |
| Vit.-A -rich fruits | HG | -0.26$^{**}$ | -0.23$^{**}$ | -0.10 | -0.10 | -0.03 | 0.01 | -0.02 | -0.05 | 0.05 | 0.05 | 0.06 | 0.09 | 0.11 | 0.13$^{*}$ | -0.07 |
| Other vegetables | HG | 0.07 | 0.06 | 0.18$^{**}$ | 0.02 | 0.00 | 0.39$^{**}$ | -0.39$^{*}$ | -0.14$^{*}$ | -0.17$^{**}$ | 0.00 | 0.02 | 0.08 | -0.01 | 0.08 | 0.06 |
| Other fruits | HG | -0.26$^{**}$ | -0.375$^{**}$ | -0.01 | 0.01 | 0.15$^{*}$ | -0.10 | 0.11 | 0.07 | 0.06 | 0.09 | 0.03 | 0.18$^{**}$ | 0.09 | 0.26$^{**}$ | 0.02 |
| Sweets | HG | -0.18$^{**}$ | -0.12$^{*}$ | -0.25$^{**}$ | 0.05 | 0.01 | -0.03 | -0.05 | -0.06 | 0.06 | -0.02 | -0.06 | -0.05 | 0.01 | -0.05 | -0.07 |
| Spices, stimulants & condiments | HG | -0.19$^{**}$ | -0.13$^{*}$ | 0.04 | -0.03 | -0.04 | -0.11 | 0.09 | 0.05 | 0.06 | 0.03 | 0.02 | 0.04 | 0.10 | 0.05 | -0.05 |
| | MTF | -0.35$^{**}$ | -0.36$^{**}$ | 0.14$^{*}$ | -0.03 | 0.12 | -0.09 | 0.12 | -0.04 | 0.13$^{*}$ | 0.15$^{*}$ | 0.01 | 0.21$^{**}$ | 0.16$^{*}$ | 0.30$^{**}$ | -0.12 |

**significant correlation at p<0.05; ** significant correlation at p<0.01; β nominal variables; wealth status '1' = poor and '3' = rich; HH = household*

Table 4-11. Pearson correlation coefficients between the species richness of marketability categories of agroforestry practices vs characteristics of households in Yayu

| Categories | AFP | Altitude | Proximity to market | Proximity to forest | Gender$^{\beta}$ | Age | Ethnicity$^{\beta}$ | Settlement history$^{\beta}$ | Education level | Religion$^{\beta}$ | Family size | Wealth status | Total land size | HG size | MCS size | MTF size |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Actively-marketed species | HG | -0.35** | -0.38** | 0.07 | 0.02 | 0.08 | 0.03 | -0.03 | -0.02 | 0.04 | 0.04 | -0.12* | 0.05 | 0.00 | 0.16* | -0.20** |
| | MCS | 0.25** | 0.29** | -0.10 | 0.11 | -0.03 | 0.11 | -0.14* | -0.13* | -0.05 | -0.18** | 0.02 | -0.09 | -0.10 | -0.13* | 0.00 |
| | MTF | -0.08 | -0.05 | -0.10 | -0.14* | 0.13* | -0.13* | 0.12* | -0.04 | 0.04 | 0.17** | 0.22** | 0.32** | 0.27** | 0.27** | 0.26** |
| Passively-marketed species | HG | 0.06 | 0.04 | -0.13* | 0.10 | 0.09 | -0.25** | 0.28** | 0.06 | 0.14* | 0.08 | 0.01 | 0.04 | 0.00 | 0.04 | 0.04 |
| | MCS | -0.20** | -0.09 | -0.02 | -0.11 | -0.10 | -0.07 | 0.08 | 0.15* | -0.07 | 0.02 | 0.01 | 0.13* | 0.04 | 0.15* | 0.00 |
| | MTF | 0.06 | 0.12 | 0.01 | -0.10 | -0.21** | -0.06 | 0.01 | 0.12* | 0.05 | -0.02 | -0.05 | -0.05 | -0.11 | -0.11 | -0.02 |
| Non-marketed species | HG | -0.06 | 0.04 | -0.21** | -0.09 | -0.06 | -0.11 | 0.08 | -0.01 | 0.07 | 0.06 | 0.16** | 0.10 | 0.20** | 0.11 | 0.03 |
| | MCS | -0.25** | -0.36** | 0.12* | -0.07 | 0.09 | -0.15* | 0.17** | 0.08 | 0.09 | 0.19** | 0.01 | 0.15** | 0.11 | 0.23** | -0.01 |
| | MTF | -0.09 | -0.13* | 0.15* | 0.04 | 0.05 | -0.01 | 0.02 | 0.06 | 0.07 | 0.08 | -0.15* | -0.06 | -0.09 | 0.03 | -0.18** |

**significant correlation at p<0.05; ** significant correlation at p<0.01; β nominal variables; wealth status '1' is for poor and '3' is for rich; HH = household*

## 4.4 Discussion

### 4.4.1 Agroforestry practices and purposes

The three major AFP, i.e. HG, MCS, and MTF, have their own primary production purposes and specific management, which enable smallholding farming households to diversify their production across the year. However, all three practices are important for sustaining the livelihoods of the households in Yayu. This was confirmed by the results of this study, as more than 80% of the households in Yayu practice all three agroforestry systems at the same time.

Each practice plays a predominant role. The MCS is managed mainly for generating money and, for the majority of households, is the main, if not the only, source of cash. The majority of farmers use MTF to produce their annual food, and HG is used for both a source of food and cash to supplement the other two practices. In the absence of either or both practices, HG importance increases, as it becomes the main source of food and/or income. Similar findings on land-use classification and functions were obtained by Kebebew and Urgessa (2011) in the Jimma area, south-western Ethiopia.

Besides these main purposes, each AFP offers additional benefits, which are more in the case of HG, as MCS and MTF have rather specific purposes. For instance, yield maximization is the main target in MCS production, so activities not directly contributing to that are discouraged. Management practices that enhance yield, like thinning, weeding and clearing, also provide useful by-products such as fuel, fodder and timber (Muleta et al. 2011).

### 4.4.2 Predominant species composition and their structural arrangement

The highest number of species were found in HG, followed by MCS and MTF. Only 19% of the species occurred in all practices, and 52% occurred in only one of the three AFP, i.e. species distribution is mainly practice/system specific. The number of species in HG is similar to values in other studies (Mekonnen et al. 2014, Mengitu and Fitamo 2016, Abebe 2005, Etissa et al. 2016).

Regarding growth habits, as expected perennial species were dominant in all AFP, but shrubs were also common being fewer in MCS and MTF due to the regular clearing to prevent competition.

Regarding agrobiodiversity, based on their origin, about 70% of the species were native, confirming that the Yayu area is naturally endowed with high species diversity. Most of the exotic species were observed in HG, followed by MTF, and MCS which is the least prone to exotic species introduction. This confirms that traditional coffee production in the MCS is more environmentally friendly than the other two practices. This is confirmed by Muleta et al. (2011) and Gole et al. (2009), who observed that local communities had proven experience in managing the naturally grown coffee crop for commercial purposes.

Regarding structural arrangements, HGs were the most complex practices with five overlapping strata. MCS, also multistorey, lacked the underground stratum due to routine clearance. In both cases, this multi-strata forest-like structure underpins farming sustainability by protecting the soil from erosion, hosting bees for pollination and honey production, buffering climatic extremes, and making a more efficient use of light, water and soil resources (Torquebiau 1992; Kehlenbeck and Maass 2004). In contrast, and due to the ecological requirements of the annual crops, MTF instead offers a zonal spatial arrangement (Das and Das 2005).

There is a remarkable dominance of individual species, especially in MCS and MTF, where *Coffea arabica* and *Zea mays*, respectively, are the most prominent. The dominance of *Zea mays* in MTF is consistent with similar reports from the Koga watershed in north-western Ethiopia (Agidie et al. 2013). In contrast, in HG the frequency distribution of dominant species was not as sharp as in MCS and MFT, as HG have multiple production objectives, i.e. stimulants, fruits, vegetables, roots and tubers, and timber. However, Kebebew and Urgessa (2011) reported that fruit trees were a dominant group of species in HG of Jimma.

### 4.4.3 Species uses and services

All three practices provide additional uses and services besides the main ones. HG was the most versatile by delivering 10 different groups of uses and services. Similar values were observed by Méndez (2011), Abebe (2013) and Senbeta et al. (2013). The types of uses and services by practice were correlated. For instance, the 'food' uses in HG were correlated with the MTF size, i.e. as the size of MTF increases, the number of food crops in HG plots decreases. Similarly, the production of 'stimulants', specifically *Coffea arabica* in HG, decreases as the households have larger MCS plots. Both assessments were confirmed by the local farmers.

Most use and service categories except 'food', 'spices, condiments, and other food & beverage additives' and 'shade trees for coffee' were provided by all AFP. Local farmers confirmed that 'fuel' is mainly a by-product of MCS pruning, weeding, thinning and clearing, whereas in HG specific species are purposefully produced such as *Vernonia amygdalina*. The situation is similar with regard to fodder, where multipurpose trees supplement the fodder obtained from the communal grazing lands (key informants communication July, 2014).

On the other hand, some uses and services are limited to specific practices. For instance, 'shade trees for coffee' was observed only in MCS and HG, as *Coffea arabica* is hardly present in MTF. Similarly, 'other services', such as 'live fence and hedge' reported as being quite relevant in the area by Etissa et al. (2016) are more important for MTF and HG than for MCS.

### 4.4.4 Food production and income generation

MTF and HG were found to be the main food supplying practices. The number of all edible species identified (80) was considerably higher than the 23 reported by Senbeta et al. (2013), and still higher than any other areas of similar ecological profile in Ethiopia. However, the authors only considered native species, while the present study covers both native and exotic species. Abebe et al. (2010) found 59 edible species in HG of Sidama, southern Ethiopia, which is lower than the 63 in the present study. Overall, these numbers reveal the high number of edible plant species with potential for food production in the Yayu AFP.

Among the identified edible species per practice, HG has the larger share of 'active food' species (82.5%) compared to only 1.5% in MCS and 20% in MTF. The dominant 'active food' crops in MTF are *Zea mays*, *Sorghum bicolor*, *Eleusine coracana* and *Eragrostis tef*, which are sources of carbohydrates and ingredients of the traditional food *Enjera*. Other second-order species are *Vicia faba* and *Pisum sativum*, which are leguminous providers of protein. Similar values, were observed in the Jimma zone (Kebebew and Urgessa 2011), and the upper Blue Nile basin (Agidie et al. 2013).

However, the seasonality in the supply of staple foods by MTF creates food gaps between seasons, which are filled with food cultivated in HG (key informants communication July, 2014). The species include *Ensete ventricosum*, which is highly appreciated and available throughout the year (Abate et al. 1996; Brandt et al. 1997; Abebe 2013; Negash and Niehof 2004), *Colocasia antiquorum*, *Dioscoreaal alta* and *Solanum tuberosum*, which during the 'food gap', are the most favored species, complemented by leafy vegetables like *Brassica oleraceae spp*. and *Brassica carinata*. Concerning the presence of 'active foods', MTF is dominated by cereals but lacking in vegetables and fruits, which are alternatively provided by HG with its broader diversity of 'active food' species from different food groups, e.g. *Carica papaya, Prunus persica*, *Daucus carot*, *Cucurbita pepo*, *Capsicum frutescens*, *Brassica oleracea*, *Brassica carinata*, etc., which are also key sources of micronutrients.

Household economic capability to acquire food in the market is key for the food access pillar (Riely et al., 1999; FAO, 2006). As revealed above, 95% of the monetary income in Yayu comes from selling *Coffea arabica* harvested from MCS. This cash is used not only to buy food but also to cover other expenditures (key informants communication July, 2014). In addition to the periodic deficit of food ('food gap'), farmers noticed a concomitant cash shortage due to the high dependency on a single cash crop, i.e. *Coffea arabica*. Alternatively, HG provides a diversity of merchantable products which can be sold throughout the year to fill that 'cash gap', e.g. dairy products, fruit, livestock, spices and even other cash crops. The findings of Etissa et al. (2016) confirm this. Similarly, in MTF, *Catha edulis* being harvested several times along the year can generate a continuous flow of cash, and in the case of annual crops, whenever surplus is achieved, this is usually supplied to the market, and/or high value cereals like *Eragrostis tef* sold to buy the cheaper *Zea mays* and *Sorghum bicolor*.

Regarding species richness of each marketability category, most species cultivated in HG such as *Catha edulis*, *Musa paradisiaca*, *Mangifera indica* and *Rhamnus prinoides* were actively sold in the area, whereas MCS and MTF were dominated by non-marketable tree species in number but not in area. This might be due to the priority given to *Coffea arabica*. Similarly, annual crops such as *Zea mays* and *Sorghum bicolor* in MTF receive more attention than other species. In general, the non-marketed species exceeded the marketability categories.

### 4.4.5 Relation between household and agroforestry attributes of Yayu

Altitude and proximity to market were found to be the most important household characteristics associated with the AFP traits considered. These results agree with those of Addi et al. (2016), who focused on the correlation of natural vegetation composition and altitude in south-west Ethiopia, and those of Bajigo et al. (2015), who observed a similar association of altitude with woody species diversity in HG of the Wolayita zone. Yayu being a biosphere reserve, the residual influence of the original vegetation on the existing AFP was expected.

Regarding the association between markets and AFP, different studies confirm both negative and positive correlations. For instance, in line with the present study, Abebe (2013) reported a positive correlation between species richness of agroforestry plots and proximity to market in the Sidama zone in Ethiopia. In contrast, Wiersum (2006), studying HG diversity in Indonesia, revealed that HG near to markets tend to be dominated by a few commercial crops. In Yayu, the major reason for higher species richness in HG near to markets may be the dominance that *Coffea arabica* already has on MCS, while the others are purposefully managed to meet both household and market demands.

Gender also correlates with richness of some species groups depending on the purpose of management, plot location and labor demand of the species. For example, cultivating legumes and cereals in MTF plots requires higher cropping and guarding labor, which the female-headed households often lack. According to the local people, the females in those households are often widows or divorced mothers. These avoid labor-demanding crops in their MTF plots and convert a share to cash-generating tree species such as

*Eucalyptus grandis* and give the rest to sharecroppers (key informants communication July, 2014).

On the other hand, the HG plots of female-headed households were rich in food groups such as vitamin-A-rich dark green vegetables and tuber and root crops, which are of great importance for food security of the households during shortage times. A study conducted on the driving forces of changes in the structure of traditional HG agroforestry of southern Ethiopia reported a more significant relation between women and food crops than between women and cash crops grown in HG (Gebrehiwot 2013).

In general, the migrant and resettled households had AFP plots less rich in native useful species including edible ones than the native households, except for the 'actively-marketed' species. This because they have relatively less knowledge about the type and uses of native plants species. According to the local people, the resettled households change the species of their AFP into merchantable exotic species more frequently than the natives. This implies that the impact of migration has a considerable impact on the environment especially on the 'non-marketable' species. Lemenih et al. (2012) confirmed the negative relationship between migration and environmental management as a lack of formal or informal structure and poor social capital with respect to the native environment.

## 4.5 Conclusions

Yayu AFP constitute a remarkable case study concerning potential local-based efforts to improve food and nutrition security. The local farmers use three different AFP, namely HG, MCS and MTF. Each has a main specialized-purpose, i.e. MTF for food production, MCS for cash generation and HG for both. Besides, inter- and intra-practice variations exist with respect to species, utilization, and management style. Despite their differences, farmers manage and utilize these practices in a synchronized way to sustain their livelihoods. We conclude that each practice contributes considerably but differently to the availability, access, utilization and stability pillars of FNS of small farming households of Yayu.

Apart from these general findings, the study acknowledges the existence of information gap regarding the detailed contribution of AFP to the current FNS of smallholding farming households in Yayu. Thus, empirical research should assess the FNS status of the smallholding farming households to relate this with the observed attributes of the AFP. The Yayu area is endowed with untapped resources of edible and marketable plants, whose contribution should be explored in depth, particularly of those within local AFP, toward the enhancement of FNS as well as the living standards of smallholding farming households of Yayu and other similar areas in developing countries.

# 5 FOOD SECURITY, DIETARY ADEQUACY, AND NUTRITIONAL STATUS OF SMALLHOLDING FARMING HOUSEHOLDS OF YAYU, SOUTH-WEST ETHIOPIA.

## 5.1 Introduction

Food and nutrition security is still a major issue in Ethiopia. Two decades ago, the country was directly associated with famine by the international community (Block and Webb 2001; von Braun and Olofinbiyi 2007). Presently, regardless of the significant risk reduction in famine occurrence, the country is home of more than 30 million undernourished people, the fourth largest number in the world (Endalew et al. 2015; FAO et al. 2015). This entails major efforts to establish polices and developmental interventions to address the problem, as the current solutions have not yet managed to guarantee total food security in the country. Among these efforts is the prominent Productive Safety Net Program (PSNP), which targets *woreda* (district equivalent of Ethiopian administrative unit) suffering from either transitory or chronic food deficits (Devereux et al. 2006). The PSNP aims at reducing the vulnerability of households to food insecurity through asset development and environment rehabilitation (Berhane et al. 2014). However, according to Rajkumar et al. (2012), information on the nutritional status per *woreda* hardly exists. Therefore, that by targeting the *woreda*, the strategy of the PSNP may be misleading when identifying the extent and degree of food-insecure households/*woreda*.

Confirming this, the analysis performed on the Welfare Monitoring Survey data (2004) revealed that differences in the prevailing rates of stunting and wasting among *woreda* defined as food insecure, partially food insecure, and food secure are not significant (Rajkumar et al. 2012). Similarly, in a cross-sectional study in the west Gojam zone, identified as a food-secure area, it was estimated that 43.2% of the children under 5 years were affected by chronic malnutrition, and 49.2% were underweight (Teshome et al. 2009). Mekonnen and Gerber (2017) cross-checked data from three pairs of neighboring food-secure *woreda* in central Ethiopia, namely Bakko and Sibu-Sire, Lume and Adaa, and Hettosa and Tiyyo, from 2004 to 2010 revealing that 27% of the households had poor or borderline caloric intake (< 2100 kcal). These findings show that areas of the country which are identified as food secure might not necessarily be such.

Furthermore, little or nothing is said with respect to the nutritional aspect of food security. Thus, conducting an assessment of people's food and nutritional status should provide a realistic backdrop to design appropriate intervention programs.

In the Yayu biosphere reserve, the case study for this research, the six *woreda* of the Illubabor zone in south-western Ethiopia have been labeled as food secure in all seasons in at least the last fifteen years (section 3.1). The zone is regarded as productive and is often the destination of communities relocated from other parts of the country exposed to recurrent famines and droughts (Gizaw 2013). Thus, it has never been included in the PSNP. The households in Yayu grow their on food on farmlands and in homegardens, and generate considerable income from coffee agroforests, so they rely equally on self-produced and purchased food (Chapter 4).

Therefore, determining the current FNS status of the local communities is of paramount importance to assess the abilities of the local farming systems to provide food (Chapter 4), and eventually to support the revision of the country's food and nutrition intervention policies and implementation programs, thus aiming at a more effective impact (Rajkumar et al. 2012). Hence, this study investigates the food and nutritional status of the smallholders in Yayu to evaluate the relationship with the AFP in the area.

The specific objectives are:

- To determine food security status, dietary habit and nutritional status of smallholding farming households of Yayu, south-west Ethiopia using different proxy tools.
- To analyze the variation in the food security status, dietary habit and nutritional status of smallholding farming households of Yayu, south-west Ethiopia across seasons and household features.

## 5.2 Methodology

### 5.2.1 Location and study design

The study focuses on smallholding farming households within the Yayu Forest Coffee Biosphere Reserve located in south-west Ethiopia (section 3.1).

The sampled households are the same as those used for assessing the farming system (Chapter 4). Out of the initial 300 households selected using a multistage random sampling, a subset of 140 households was obtained. The assessment criteria were the existence of non-breast feeding children (NBF) children under 5 years, and women of reproductive age (WRA) between 15 and 45 years of age, generally the mother of the considered child. In the case where more than one child existed in the sampled household, the youngest was chosen, and in the case of twins a lottery was applied (Mulu and Mengistie 2017).

Data collection took place between December 2014 and August 2016 in order to cover the food surplus and food shortage season (section 3.1)

### 5.2.2 Data collection and analyses

Five different types of data were collected: (1) Household background, which included age, gender, educational status, ethnicity, religion, settlement history, family size and wealth status. The household head provides answers to these questions except for the wealth status, which was provided by the local administrative office. (2) Household food-security status was assessed by interviewing the households for a reference period of four weeks. (3) The household dietary pattern was assessed by estimating the food consumption history of 12 food groups in 3 time references, i.e. 24 hours, 7 days and 4 weeks. (4) Household dietary adequacy was assessed through the individual dietary intake history (type and frequency of food items consumed) in the previous 24 hours and 7 days. Finally, (5) Nutritional status of the households was assessed through anthropometric measurements, such as body weight and height of the target children and non-pregnant women. Electronic scales precise to 100 g, and wooden collapsible length/height measuring devices precise to 1 mm were used. The age of the children was captured considering month and year, whereas for women it was registered in years. Moreover, the overall health, edema (for children) and pregnancy status were directly observed.

The person mainly responsible for food preparation in the household was asked for the food security and dietary history questions; for the child, the main caregiver was asked. Dietary history survey and food security questions were asked at different times of the day, thus preventing confusion in the interviewees, and fatigue of the respondent and enumerators. Female enumerators were recruited and trained among the local health extension agents. These were chosen based on their familiarity with dietary assessments and anthropometric measuring and ease access to the target groups. Surveys were pre-tested on 10 Yayu town households, and adjusted before application. Originally prepared in English, the surveys were translated into Amharic and administered either in Amharic or Oromiffa. Responses were later translated back into English to crosscheck response accuracy. Finally, all household heads, and parents or guardians in the case of children, were informed about the objectives and confidentiality of the study, and a verbal and written consent obtained.

### Household food security

The food security status of the households was assessed using three standard tools, i.e. HHS (Ballard et al. 2011), HFIAS (Coates et al. 2007a), and HDDS (Kennedy et al. 2011). The HHS was used to determine the level of hunger in a household. The HFIAS was formulated for the past 4 weeks to measure the level of food insecurity in a household. Finally, HDDS was used to approach the adequacy of dietary energy in the samples. For the first scales, standard cutoff points were used (section 2.1.4), whereas for HDDS the scores were grouped into three food security (tertiles) categories of relative representativeness, i.e. 'low', 'medium' and 'high'.

### Dietary pattern and nutrient adequacy

After determining the food security status, the second step was to uncover how the food consumed potentially contributed to the household nutrition. This was performed by dietary pattern and nutrient adequacy determination. The dietary pattern was done at the household level by recording the food consumption history in three time reference periods, i.e. 24 hours, 7 days and 4 weeks, and then summarizing the belonging of the food items to the 12 food groups (Swindale and Bilinsky 2006).

The nutrient adequacy determination for the two target groups was achieved using two proxy tools, i.e. Food Consumption Score (FCS) and Individual Dietary Diversity Score (IDDS) applied for two reference periods, 7 days and 24 hours, respectively. For the FCS, the food consumption history (type and frequency of each food consumed) was reclassified into 9 food groups to build the score for each target individual (WFP-VAM 2008). The frequency of each food group was weighted by the specific values given by the World Food Program (WFP) and summed up to provide individual FCS that could be contrasted against standardized cut-off points (WFP-VAM 2008). Standard cut-off points were used to categorize the sample household based on its nutrient adequacy level (section 2.1.4).

For IDDS, the dietary intake history of the target individual for the previous 24 hours was summarized into 9 food groups following the procedure given by FANTA (Kennedy et al. 2011). Unlike FCS, all food groups had the same weight and one/zero scores were given for their absence/presence. Finally, each score was summed up to calculate the IDDS of each sample individual, which was grouped in tertiles of adequacy/diversity as recommended by Kennedy et al. (2011), i.e. ‘low’, ‘medium’ and ‘high’.

Finally, a detailed analysis of the level of adequacy of three important nutrients, namely protein, vitamin A, and heme iron[5] was carried out (WFP-VAM 2008) for FCS and IDDS. These micronutrients were selected because they can be easily identified in the food group consumption patterns (WFP-VAM 2015). Thus, the consumption frequency of food groups, identified as a potential sources of these nutrients, were summarized for each target group in two seasons.

**Nutritional status**

Nutritional status was assessed via different anthropometric measurements applied to the two target groups. For the NBF under 5 years, the Multicentre Growth Reference

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[5] This study focused on heme iron rather than non-heme iron. The former is found in meat and fish and is well absorbed (10-30%), while the latter is found in cereals, fruit, vegetables and dairies and only 1-5% is absorbed (WHO and FAO 2004).

Study (MGRS) (WHO 2006) method was applied. Three z-score indicators, i.e. weight for height z-score (WHZ), weight for age z-score (WAZ), and height for age z-score (HAZ) were used to determine the nutritional status of the target child (WHO 2006). The z-scores were calculated using equation 5.1.

$$\boldsymbol{z\text{–}score}_{\mathrm{ij}} = \frac{\left(\boldsymbol{X}_{\mathrm{ij}} - (\boldsymbol{Reference\ median}_{\mathrm{i}})\right)}{\boldsymbol{SD}_{\mathrm{i}}} \text{………………….Equation (5.1)}$$

*Where Xi = measurement of jth child at ith age/height; Reference median = median of the reference population at ith age/height; SDi = standard deviation of the reference population at ith age/height.; Reference population was obtained from WHO (2006); age in months; weight in kg and height in cm.*

Finally, the scores were compared to the standard nutritional status cut-off points (Table 2-1).

Regarding WRA, the body mass index (BMI) (Equation 5.2) was used and later compared to the combined four categories obtained from the WHO (1999) and FANTA (2016) standards (Table 2-2).

$$\boldsymbol{BMI}_{\mathrm{i}} = \frac{(\boldsymbol{Wt}_{\mathrm{i}})}{\boldsymbol{Ht}_{\mathrm{i}}{}^{2}} \text{ …………………………………….………….Equation (5.2)}$$

*Where Wti = weight of ith in kg; Hti = height of ith in cm.*

Statistical analyses included the estimation of descriptive statistics such as mean, median and frequency of samples concerning relevant parameters of food and nutrition security. Variabilities and distributions among categories were tested using the parametric F-test. For the seasonal variation of scores, the paired t-test was applied. For children-women comparison two sample t-tests were employed. Pearson correlation analysis was employed to detect associations among attributes. Microsoft Excel 2013, Minitab 17.1.0, and ENA for SMART software were used.

## 5.3 Results

### 5.3.1 Socioeconomic profiling

The food and nutrition situation of the sample households can be assumed to have a relationship with their socioeconomic and demographic characteristics. Out of the 140 sample households, 94.3% were male headed. Around 70% of the male household heads were between 21 and 40 years of age. The average age of the household members was 37.1 ± 11.3. Of the sample households, 84% were native, while 15% were households resettled from other regions of the country. 38.6% of the household heads (the highest among males) had reached at least elementary school level (grade 1-6). The household average school attendance time was 1.5 ± 0.5 years. Another household attribute was ethnicity: 'Oromo' was the dominant group (75.5%) followed by Amhara (15.7%). Regarding household size, 90% had 4 to 9 members, and an average of 5.7 ± 1.3 members. 47.9% of the households were regarded as poor, and 18.9% as rich (Table 5-1).

Table 5-1. Socioeconomic and demographic attributes of sample households

| Household characteristic | Levels/classes | n (%) |
|---|---|---|
| Gender of household head | Male | 133(95) |
| | Female | 7(5) |
| Age classes | <=20 | 1(0.7) |
| | 21-30 | 54(38.6) |
| | 31-40 | 46(32.9) |
| | 41-50 | 24(17.1) |
| | 51-60 | 10(7.1) |
| | 61-70 | 3(2.1) |
| | >=71 | 2(1.4) |
| | Mean±SD | 37.1±11.3 |
| Settlement history | Settled from another region | 21(15) |
| | Moved within the region | 1(0.7) |
| | Native | 118(84.2) |
| Educational status | Not attended school | 39(27.9) |
| | Basic education | 9(6.4) |
| | Elementary school, grade 1-6 | 54(38.6) |
| | Junior school, grade 7-8 | 24(17.1) |
| | Secondary school, grade 9-10 | 12(8.6) |
| | Above grade 10 | 2(1.4) |
| | Mean±SD | 1.8±1.3 |
| Ethnicity | Oromo | 106(75.7) |
| | Amhara | 22(15.7) |
| | Tigireway | 9(6.4) |
| | Other | 3(2.1) |
| Religion | Orthodox | 56(40) |
| | Muslim | 52(37.1) |
| | Protestant | 32(22.9) |
| Family size | 2-3 | 21(15) |
| | 4-5 | 52(37.1) |
| | 6-7 | 39(27.9) |
| | 8-9 | 22(15.7) |
| | 10-11 | 5(3.6) |
| | 12-13 | 1(0.7) |
| | Mean±SD | 5.7±2.1 |
| Wealth classes | Poor | 67(47.9) |
| | Medium | 47(33.6) |
| | Rich | 26(18.8) |

### 5.3.2 Food security status

Based on the HHS, there was no hunger during the surplus season, and more than 83% of the households were also hunger-free even in the shortage season. Out of the 23 (15.5%) households detected as ‘hungry’, only 2 were severely affected, while the rest were in the category ‘moderate hunger’ during the shortage season. After fine-tuning the HHS results with the 9 HFIAS questions, the proportion of food-secure households in the surplus season was reduced to 70.7%, and in the shortage season dropped to 18.5%. The mean HFIAS indices were 1.6 ± 3.0 (surplus season) and 10.3 ± 6.2 (shortage season). Most sampled households had medium access to the optimum dietary energy in all seasons, i.e. 23.5% during the shortage and 16.4% during the surplus season. The average HDDS was 6.7 ± 1.2 (surplus season) and 6.4 ± 1.1 (shortage season) (Table 5-2).

Pearson correlation analysis was performed on household attributes and the three food security status scores. Wealth is significantly correlated (p<0.01) with all scores except for HHS and HDDS during the surplus season; the highest value was with HFIAS (r=-0.88) and the weakest with HDDS (r=-0.48). Family size was also significantly correlated with HFIAS in both seasons, and with HDDS in the shortage season. The educational status of the person responsible for food preparation showed highly significant correlation with HDDS in the surplus season (r=-0.30, p<0.01). During the shortage season, gender of the household head also showed significant correlation with HHS and HDDS (Table 5-3)

Table 5-2. Count, proportion, and average (±standard deviation) scores of households in different categories of food security and their varaiation in seasons of Yayu.

| Score | Category | Surplus season | | Shortage season | |
|---|---|---|---|---|---|
| | | Mean±SD | n (%) | Mean±SD | n (%) |
| HHS | Little to no hunger | 0.01±0.1 | 140(100.0) | 0.3±0.4$^{C}$ | 117(83.6) |
| | Moderate hunger | N.A | 0(0.0) | 3.2±1.0$^{B}$ | 21(15.0) |
| | Severe hunger | N.A | 0(0.0) | 6.5±0.7$^{A}$ | 2(1.4) |
| | Category variation | N.A | | p<0.01 | |
| | Average/total | 0.01±0.1 | 140(100.0) | 0.8±1.4 | 140(100.0) |
| | Seasonal variation | p<0.01 | | | |
| HFIAS | Food secure | 0.2±0.4 $^{C}$ | 99(70.7) | 0.0±0.0$^{C}$ | 26(18.6) |
| | Mildly food insecure | 4.3±1.7 $^{B}$ | 39(27.9) | 6.5±0.7$^{B}$ | 12(8.6) |
| | Moderately food insecure | N.A | 0(0.0) | 12.9±2.4$^{A}$ | 48(34.3) |
| | Severely food insecure | 19.0±0.00 $^{A}$ | 2(1.4) | 14.7±4.3$^{A}$ | 54(38.6) |
| | Category variation | p<0.01 | | p<0.01 | |
| | Average/total | 1.6±3.0 | 140(100.0) | 10.3±6.2 | 140(100.0) |
| | Seasonal variation | p<0.01 | | | |
| HDDS | Low | 4.9±0.2$^{C}$ | 23(16.4) | 4.9±0.3$^{C}$ | 33(23.6) |
| | Medium | 6.4±0.5$^{B}$ | 78(55.7) | 6.5±0.5$^{B}$ | 86(61.4) |
| | High | 8.2±0.5$^{A}$ | 39(27.9) | 8.2±0.4 $^{A}$ | 21(15.0) |
| | Category variation | p<0.01 | | p<0.01 | |
| | Average/total | 6.7±1.2 | 140(100.0) | 6.4±1.1 | 140(100.0) |
| | Seasonal variation | p<0.012 | | | |

** *Categories values with same superscript do not differ significantly at α=0.05; N.A = statistical test not applicable*

Table 5-3. Correlation coefficient among food security scores and characteristics of households in surplus and shortage seasons in Yayu

| Household characteristics | HHS | | HFIAS | | HDDS | |
|---|---|---|---|---|---|---|
| | Surplus | Shortage | Surplus | Shortage | Surplus | Shortage |
| Head age | -0.07 | -0.07 | -0.21$^{*}$ | -0.28$^{**}$ | -0.04 | 0.21$^{*}$ |
| Head settlement history$^{\beta}$ | 0.05 | 0.12 | 0.09 | 0.17$^{*}$ | 0.10 | -0.11 |
| Head educational status | 0.07 | -0.02 | 0.04 | 0.08 | 0.14 | 0.03 |
| Head ethnicity$^{\beta}$ | -0.06 | -0.16 | -0.14 | -0.20$^{*}$ | 0.07 | 0.17$^{*}$ |
| Head religion$^{\beta}$ | 0.10 | 0.02 | 0.16 | 0.03 | 0.01 | -0.07 |
| PRFP age | -0.08 | 0.10 | -0.14 | -0.19* | 0.05 | 0.04 |
| PRFP settlement history$^{\beta}$ | 0.05 | 0.12 | 0.01 | 0.05 | 0.05 | -0.01 |
| PRFP educational status | 0.08 | 0.07 | 0.13 | 0.16 | 0.30$^{**}$ | -0.11 |
| PRFP ethnicity $^{\beta}$ | -0.06 | -0.09 | -0.06 | -0.07 | 0.05 | 0.05 |
| PRFP religion $^{\beta}$ | 0.11 | 0.03 | 0.15 | 0.03 | 0.01 | -0.06 |
| Family size | -0.13 | 0.06 | -0.24$^{**}$ | -0.25$^{**}$ | 0.04 | 0.18$^{*}$ |
| Wealth status | -0.11 | -0.50$^{**}$ | -0.44$^{**}$ | -0.88$^{**}$ | 0.16 | 0.48$^{**}$ |

*PRFP = person responsible for food preparation; *significant at p<0.05; ** significant at p<0.01; β = attributes with nominal values; N.B. negative 'r' values do not show the direction of correlation except those variable with nominal value*

### 5.3.3 Dietary pattern

Considering 12 food groups, 3 time references, and the surplus and shortage seasons, it was found that cereals, oil and fats, vegetables, and spices, condiments and beverages were the most frequently consumed food groups scoring above 98% in the households in both seasons and all reference periods. Some food groups, such as white tubers and dairy products showed higher consumption frequencies during the shortage season, while the remaining food groups showed higher consumption frequency during the surplus season. When the consumption patterns of these food groups are compared across the three time preferences, only the food group ‘fish‘ is consistently absent in the general diet of the Yayu community (Figure 5-1).

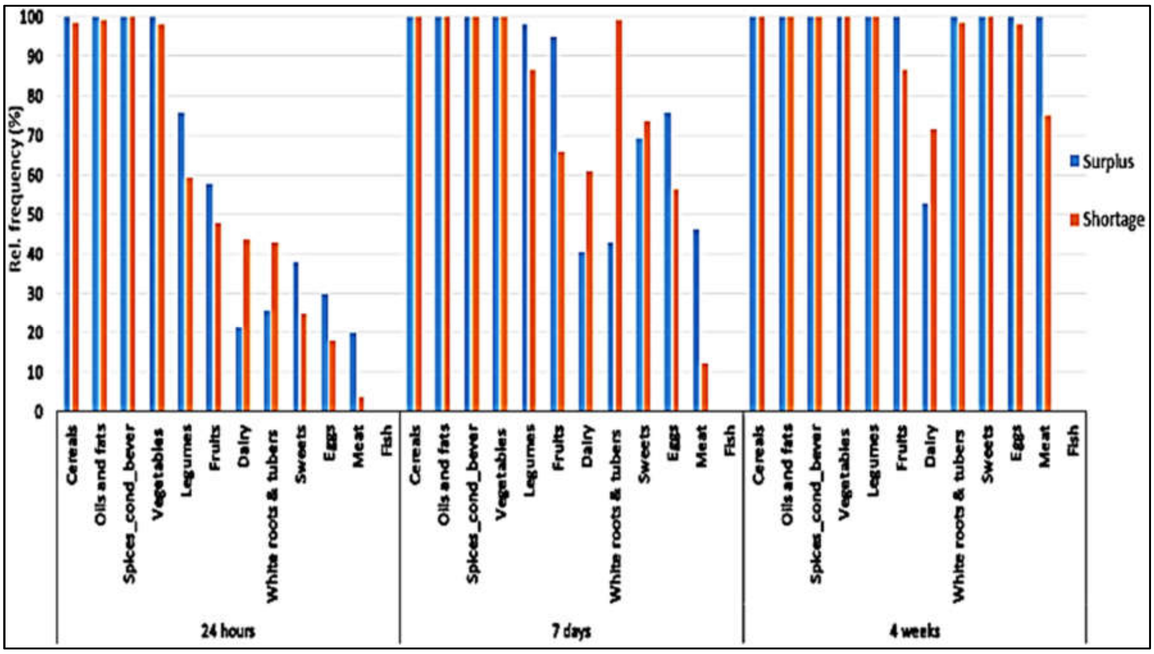

Figure 5-1. Relative consumption frequency of 12-food groups during two seasons and three reference periods of households in Yayu.

### 5.3.4 Dietary adequacy

**Weekly food consumption score**

Based on the standard FCS cutoff points, there was no ‘poor’ food consumption, as more than 87% of the children and women were in the category ‘acceptable’. The mean 7-day weighted FCS for NBF children under 5 years was 53.5 ± 14.2 and 56.3 ± 18.1, and for WRA

52.4 ± 1.1 and 54.6 ± 15.7, for the surplus and shortage season, respectively. Weighted FCS means of both target groups were higher in the shortage season ($p<0.05$) (Table 5-4). Apart from this, there was no significant difference among target groups.

Table 5-4. Weekly Food Consumption Score variation of target groups across categories and seasons in Yayu.

| **Target groups** | **Category** | **Surplus season** | | **Shortage season** | |
|---|---|---|---|---|---|
| | | **Mean±SD** | **n (%)** | **Mean±SD** | **n (%)** |
| NBF children <5 yrs. | Poor | - | - | - | - |
| | Borderline | $31.6±2.6^{B}$ | 17(12.4) | $30.2±3.3^{B}$ | 15(10.7) |
| | Acceptable | $56.9±12.4^{A}$ | 123(87.6) | $59.5±16.6^{A}$ | 125(89.3) |
| | Category variation | P<0.01 | | P<0.01 | |
| | Average/total | 53.5±14.2 | 140(100.0) | 56.3±18.1 | 140(100.0) |
| | Season variation | p = 0.018 | | | |
| WRA | Poor | - | - | - | - |
| | Borderline | $30.2±3.6^{B}$ | 13(9.2) | $30.2±3.2^{B}$ | 15(10.7) |
| | Acceptable | $54.6±12.5^{A}$ | 127(90.7) | $57.5±13.9^{A}$ | 125(89.3) |
| | Category variation | P<0.01 | | P<0.01 | |
| | Average/total | 52.4±13.4 | 140(100.0) | 54.6±15.7 | 140(100.0) |
| | Season variation | p = 0.046 | | | |
| Target group variation | | P = 0.686 | | P = 0.791 | |

** Categories values with the same superscript do not differ significantly at α=0.05*

A further analysis on the 7-day food consumption score for assessing the status of key micronutrient intake (vitamin A, protein and heme iron) shows that 6.4% and 17.9% of NBF children under 5 years and WRA, respectively, did not consume any vitamin-A-rich food group during the surplus period. No seasonal variation was observed regarding consumption of protein-rich foods among children, but 3.6% of women showed a no consumption during the lean season. The most critical result was observed regarding foods rich in heme iron, as more than 50% of both target groups lacked those foods, even in the surplus season, which increased up to 87.9% in the shortage season (Figure 5-2).

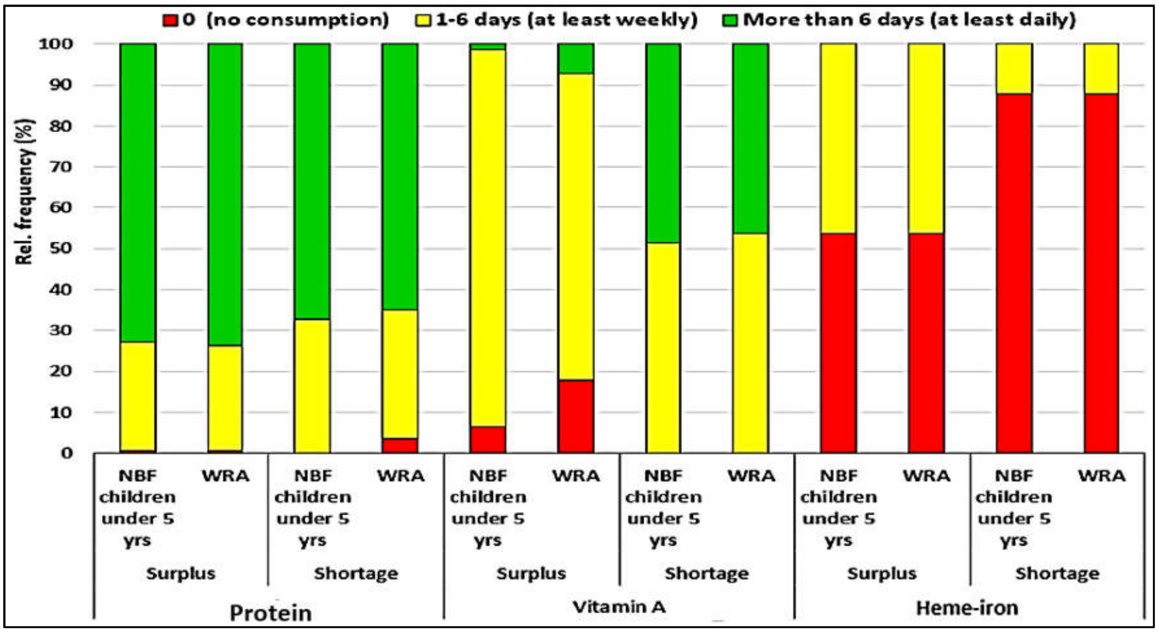

Figure 5-2. Weekly food consumption frequency of target groups of food groups rich in three key micronutrients during surplus and shortage seasons in Yayu

**Daily individual dietary diversity score**

The daily dietary intake-based adequacy evaluation revealed that 38.6% and 42.9% of the children and women had a relatively low diversity dietary intake during the shortage period. The daily IDDS had no significant seasonal variation. In contrast, the score of children and women differed significantly only during the surplus period ($p<0.01$). In general, the mean IDDS value of children was 3.9 ± 0.9 and 3.8 ± 1.0, and that of the women 3.6 ± 0.8 and 3.8 ± 1.2 in the surplus and shortage seasons, respectively (Table 5-5).

The analyses on the daily consumption frequency of key micronutrients showed that the consumption of vitamin A in some households increases in the surplus season (4-times instead of 3-times) for both children and women. In contrast, the overall consumption were better in the shortage season as proportion of no consumption of vitamin A reduced by 17.9% and 24.3% of target children and women, respectively. In the case of protein, consumption increases slightly in the surplus season for children (5-fold) but remains relatively constant for women (4-times). About 5% of the children and 7% of the women did not receive the optimal daily ration of protein during the surplus season, but the share increased to 19.3% and 21% in the shortage season. As for heme iron, frequency increases in the surplus season between 2- and 3-fold. However, 80% of the children and 96.4% of the women did not consume such foods regardless the season (Figure 5-3).

Table 5-5. Variation of Daily Individual Dietary Diversity Scores of target groups across categories and seasons in Yayu.

| Target group | Category | Surplus season | | Shortage season | |
|---|---|---|---|---|---|
| | | Mean ± SD | n (%) | Mean ± SD | n (%) |
| NBF children <5 yrs. | Low | 3.0±0.1$^{C}$ | 53 (37.8) | 2.8±0.4$^{C}$ | 54(38.6) |
| | Medium | 4.0± 0.0$^{B}$ | 54 (38.6) | 4.0± 0.0$^{B}$ | 50(35.7) |
| | High | 5.4±0.6$^{A}$ | 33 (23.6) | 5.1±0.3$^{A}$ | 36(25.7) |
| | Category variation | P<0.01 | | P<0.01 | |
| | Average/total | 3.9±0.9 | 140(100.0) | 3.8±1.0 | 140(100.0) |
| | Season variation | p= 0.215 | | | |
| WRA | Low | 3.0±0.2$^{C}$ | 73 (52.1) | 2.7±0.4$^{C}$ | 60(42.9) |
| | Medium | 4.0±0.0$^{B}$ | 48 (34.28) | 4.0± 0.0$^{B}$ | 45(32.1) |
| | High | 5.2±0.5$^{A}$ | 19 (13.6) | 5.1±0.3$^{A}$ | 35(25.0) |
| | Category variation | P<0.01 | | P<0.01 | |
| | Average/total | 3.6±0.8 | 140(100.0) | 3.8±1.2 | 140(100.0) |
| | Season variation | p= 0.225 | | | |
| Target variation | | P<0.01 | | p=0.545 | |

** Category values with the same superscripts do not differ significantly at α=0.05*

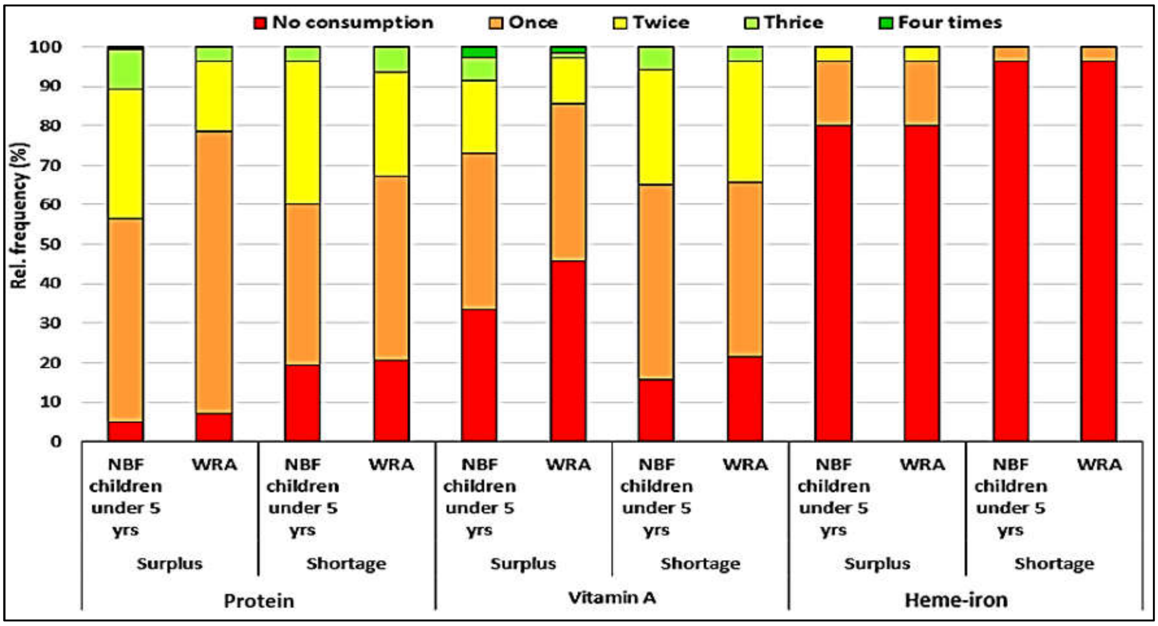

Figure 5-3. Daily food consumption frequency of target groups of food groups rich in three key micronutrients across seasons in Yayu.

The correlation analysis carried out among the calculated variables shows that the wealth status of the households is significantly correlated with the FCS and IDDS for both target groups in both seasons. The strongest correlation was between the FCS of both targets with wealth status ($r=0.81$; $p<0.01$), and the weakest was with WRA during the surplus season ($r=0.22$; $p<0.05$). Another important correlation was observed with the ethnicity of the household head, which was significant with all classes of indices, targets and seasons. A significant correlation was also observed with the ethnic background of the PRFP except for the FCS of the surplus season of both target groups. (Table 5-6).

Table 5-6. Correlation between Food Consumption Score and the Individual Dietary Diversity Score of the two target groups against household characteristics in surplus and shortage seasons in Yayu

| **Household characteristic** | **NBF children under 5 yrs.** | | | | **WRA** | | | |
|---|---|---|---|---|---|---|---|---|
| | **FCS** | | **IDDS** | | **FCS** | | **IDDS** | |
| | **Surplus** | **Shortage** | **Surplus** | **Shortage** | **Surplus** | **Shortage** | **Surplus** | **Shortage** |
| Head age | $0.20^{*}$ | $0.23^{**}$ | -0.08 | 0.15 | 0.19* | $0.20^{*}$ | -0.03 | 0.152 |
| Head settlement history | -0.17 | $-0.25^{**}$ | $-0.17^{*}$ | $-0.23^{**}$ | -0.15 | $-0.24^{**}$ | $-0.21^{*}$ | $-0.26^{**}$ |
| Head educational status | -0.01 | -0.08 | 0.07 | -0.03 | 0.01 | -0.05 | 0.05 | -0.044 |
| Head ethnicity$^{\beta}$ | $0.24^{*}$ | $0.27^{**}$ | $0.33^{**}$ | $0.28^{**}$ | $0.23^{**}$ | $0.25^{**}$ | $0.31^{**}$ | $0.29^{**}$ |
| Head religion$^{\beta}$ | -0.08 | -0.15 | 0.01 | -0.10 | -0.09 | -0.15 | 0.05 | -0.074 |
| PRPF age | 0.21 | 0.15 | -0.01 | 0.08 | $0.19^{*}$ | 0.13 | -0.01 | 0.092 |
| PRPF settlement history$^{\beta}$ | -0.04 | $-0.22^{*}$ | $-0.18^{*}$ | -0.10 | -0.04 | $-0.21^{*}$ | $-0.17^{*}$ | -0.078 |
| PRPF educational status | -0.09 | -0.09 | $0.25^{**}$ | $-0.17^{*}$ | -0.08 | -0.04 | $0.23^{**}$ | $-0.18^{*}$ |
| PRPF ethnicity $^{\beta}$ | 0.11 | $0.23^{**}$ | $0.23^{**}$ | $0.17^{*}$ | 0.12 | $0.24^{**}$ | $0.17^{*}$ | $0.17^{*}$ |
| PRPF religion $^{\beta}$ | -0.07 | -0.14 | -0.03 | -0.11 | -0.09 | -0.14 | 0.01 | -0.083 |
| Family size | $0.29^{**}$ | 0.21* | 0.04 | $0.19^{*}$ | $0.26^{**}$ | $0.17^{*}$ | 0.05 | $0.20^{*}$ |
| Wealth status | $0.81^{**}$ | $0.73^{**}$ | $0.26^{**}$ | $0.56^{**}$ | $0.81^{**}$ | $0.68^{**}$ | 0.22* | $0.55^{**}$ |

*PRPF = person responsible for preparing food; *significant at $p<0.05$; ** significant at $p<0.01$; β = attributes with nominal values; N.B. negative 'r' values do not show the direction of correlation except those variables with nominal value; wealth status 1 = poor and 3 = rich.*

### 5.3.5 Nutritional status

**NBF children under 5 years**

The distribution of WHZ scores of NBF children under 5 years in Yayu shows that 2.9% and 3.9% of the children were wasted in the surplus and shortage seasons, respectively. The comparison of the WAZ scores against standard cut-off values (table 2-1) reveals that about 5% and 10% of the children were underweight, out of which 1.2% and 2.4% were severely underweight during the surplus and shortage seasons, respectively. The distribution of the HAZ shows the prevalence of stunting of 17% and 38% of which 1.4% and 9.2% were severely stunted during the surplus and shortage seasons, respectively (Table 5-7).

Table 5-7. Prevalence of malnutrition of children under 5 years during surplus and shortage seasons in Yayu

| **Malnutrition category** | **Prevalence of malnutrition n (%), (C.I. 95%)** | |
|---|---|---|
| | **Surplus season** | **Shortage season** |
| Wasted | 4(2.9%)(0.1-5.6) | 3(3.9%)(-0.4-8.3) |
| Moderate | 3(2.1%)(-0.3-4.5) | 3(3.9%)(-0.4-8.3) |
| Severe | 1(0.7%) (-0.7-2.1) | 0(0.0 %)(0.0-0.0) |
| Underweight | 7(5.0 %)(1.4-8.6) | 8(10%)(3.6-17.4) |
| Moderate | 5(3.6%)(0.5-6.6 ) | 6(7.9%)(1.8-14.0) |
| Severe | 2(1.4%)(-0.5-3.4 ) | 2(2.6%)(-1.0-6.2 ) |
| Stunted | 25(17.9%)(11.5-24.2) | 29(38.2%)(27.2-49.1) |
| Moderate | 23(16.4%)(10.3-22.6) | 22(28.9%)(18.8-39.1) |
| Severe | 2(1.4%)(-0.5-3.4 ) | 7(9.2%)(2.7-15.7) |

**Women of reproductive age**

The distribution of the BMI of WRA showed that 10.9% were malnourished in the surplus season and 13.6% in the shortage season, while 87.6% and 83.4% were between the normal ranges in the surplus and shortage season, respectively (p<0.01). Tests of variation across the malnutrition categories and seasons revealed a highly significant variation (p<0.01) (Table 5-8).

Table 5-8. Mean, proportion (%) and test of variation of BMI-based nutrition category of women of reproductive age during surplus and shortage seasons in Yayu

| **Malnutrition category** | **Surplus season** | | **Shortage season** | |
|---|---|---|---|---|
| | **Mean ± SD** | **n (%)** | **Mean ± SD** | **n (%)** |
| Malnourished | $17.8\pm0.6^{C}$ | 14 (10.9) | $17.7\pm0.8^{C}$ | 19(13.6) |
| Severe | N.A | 0(0.0) | 15.8±0.1C | 2 (1.7) |
| Moderate | $16.5\pm0.1^{C}$ | 2(1.6) | N.A | 0(0.0) |
| Mild | $18.0\pm0.4^{C}$ | 12(9.3) | 18.0±0.4C | 14(11.6) |
| Normal | $20.8\pm 1.4^{B}$ | 113 (87.6) | $20.9\pm1.5^{B}$ | 101(83.4) |
| Overweight | $25.2 \pm0.2^{A}$ | 2(1.6) | $26.1\pm2.0^{A}$ | 4(3.3) |
| Obese | N.A | 0(0.0) | N.A | 0(0.0) |
| Category variation | P <0.01 | | P <0.01 | |
| Average/Total | 20.6±1.7 | 129(100.0) | 20.6±2.1 | 121(100.0) |
| Season variation | P <0.01 | | | |

**Categories values with same letter do not differ significantly at α=0.05; N.A = statistical test not applicable*

The Pearson correlation analysis shows that the all anthropometric indicators of NBF children under 5 years in both seasons were positively associated with the wealth status of the households (r=0.27 - 0.52; p<0.01). In addition, the wealth status had a positive correlation with the BMI of WRA (r=0.21; p<0.05). Compared against the z-scores, age of the household head showed a positive correlation with the WAZ and HAZ in both seasons. In addition, the HAZ indicator was also positively correlated with the educational level of the PRFP in both season (Table 5-9).

Table 5-9. Correlation between anthropometric variables of NBF children under 5 years against household characteristics during surplus and shortage seasons in Yayu

| Household characteristic | NBF children under 5 yrs. | | | | | | WRA | |
|---|---|---|---|---|---|---|---|---|
| | HAZ | | WHZ | | WAZ | | BMI | |
| | Surplus | Shortage | Surplus | Shortage | Surplus | Shortage | Surplus | Shortage |
| Head age | 0.24** | 0.30** | 0.15 | 0.16 | 0.25** | 0.33** | 0.02 | 0.01 |
| Head settlement history$^{\beta}$ | -0.03 | -0.04 | -0.13 | -0.04 | -0.10 | -0.06 | 0.03 | -0.07 |
| Head educational status | -0.14 | -0.21 | -0.07 | 0.01 | -0.12 | -0.15 | -0.06 | -0.07 |
| Head ethnicity$^{\beta}$ | 0.05 | 0.01 | 0.07 | 0.07 | 0.08 | 0.04 | -0.04 | 0.05 |
| Head religion$^{\beta}$ | -0.07 | -0.10 | -0.16 | -0.15 | -0.15 | -0.17 | 0.07 | 0.06 |
| PRPF age | 0.10 | 0.22 | 0.14 | 0.09 | 0.15 | 0.23 | 0.03 | 0.06 |
| PRPF settlement history$^{\beta}$ | -0.04 | -0.06 | -0.05 | 0.11 | -0.06 | 0.02 | 0.12 | 0.05 |
| PRPF educational status | -0.24** | -0.31** | -0.05 | -0.01 | -0.17 | -0.24* | -0.12 | -0.06 |
| PRPF ethnicity$^{\beta}$ | 0.01 | -0.01 | -0.04 | -0.12 | -0.03 | -0.08 | -0.11 | 0.08 |
| PRPF religion$^{\beta}$ | -0.05 | -0.07 | -0.16 | -0.15 | -0.13 | -0.15 | 0.12 | 0.08 |
| Family size | 0.13 | 0.23* | 0.10 | 0.14 | 0.15 | 0.26* | -0.06 | -0.01 |
| Wealth status | 0.36** | 0.43** | 0.27** | 0.30** | 0.41** | 0.52** | 0.04 | 0.21* |

*PRPF = person responsible for preparing food; *significant at p<0.05; ** significant at p<0.01; β = attributes with nominal values; N.B. negative 'r' values do not show the direction of correlation except those variables with nominal value; wealth status 1 = poor and 3 = rich.*

## 5.4 Discussion

### 5.4.1 Food security status

It was observed that Yayu communities do not suffer from hunger during the surplus season. This partly agrees with the annual food security outlook reports of the Famine Early Warning Systems Network from 2005 onwards, which labels Yayu a hunger-free zone (FEWS NET 2005-2017). However, about 16% of the households were affected by hunger during the shortage season, out of which 1.4% were in the 'severely hungry' category. These findings indicate that the seasonal fluctuation in food and cash may have been ignored during previous assessments of food insecurity. Nevertheless, the majority of the smallholding farming households in Yayu can still be regarded as hunger free.

Concerning HFIAS, values of both the surplus and shortage season differed from the national average values of 6.7±6.7 reported by Ali et al. (2013). In Sidama, southern Ethiopia, Jory et al. (2011) observed HFIAS values of 3.6 and 8.8 for the surplus and shortage season, respectively. In the same line, Gebreyesus et al. (2015) reported a mean HFIAS of 6.4 for the Gurahgae zone, also labeled as food secure. During the surplus season in Yayu all cases showed higher food security than other food-secure areas of the country. On the contrary, the food insecurity value in Yayu during the shortage season was slightly higher than in those areas. This might be due to the skewed dependency of Yayu communities on marketed food rather than on their own products, specifically during the shortage season.

Another aspect of the food security status relates to the economic capability of the households to acquire a variety of food, an issue tackled by the HDDS. The average HDDS of Yayu was 6.7±1.2 and 6.4±1.1 for the surplus and shortage season, respectively. The mean value of the surplus season was similar to the national average (6.7) but higher than that of the shortage season (5.9) (Hirvonen et al. 2015). Also, the Welfare Monitoring Survey Ethiopia (Workicho et al., 2016) reported a mean HDDS value of 5.0±1.9, which is lower than the values in both seasons in Yayu. In similar reports by Coates and Galante (2014) and Gebreyesus et al. (2015), similar seasonal fluctuations of HDDS were described.

The association observed between the food security status of the households and their respective wealth status are in agreement with the study performed on Sidama communities in southern Ethiopia (Regassa and Stoecker 2012). According to the *woreda* administrative office who provided the wealth status data, the main criteria for wealth estimation is the landholding size, which may directly relate to the amount of food and cash that a given household can obtain. This assessment agrees with the findings of the present study regarding household size, which is identified as a key driver of household food security.

### 5.4.2 Dietary pattern

The comparison of the general dietary pattern of smallholding farming households in Yayu with the findings in reports by Coates and Galante (2014) and Workicho et al. (2016) is presented in Table 5-10. The comparison shows the predominance of a cereal-based diet where consumption values are equivalent to the national average values; the same applies to tubers. However, tuber consumption doubles during the shortage season. This is because white tubers, which are often considered as shortage time foods, are readily available during the shortage season.

Concerning other food groups, weekly consumption was higher in Yayu than the national averages, even during the shortage season, with the exception of meat where consumption is particularly low in the shortage time, and fish that is not consumed in any season. Workicho et al. (2016) reported a negligible trend of fish consumption in the Oromia region. In the present study, the share of consumed legumes was 97.7% and 86.4% during the surplus and shortage season, respectively, which are is higher than the values of all regions studied by Coates and Galante (2014).

Table 5-10. Comparison of weekly consumption trend of food groups in all regions in Ethiopia against Yayu values.

| Food group | National and regional level | | Yayu | |
|---|---|---|---|---|
| | All regions[a] | All regions except three pastoral regions [b] | Surplus season | Shortage season |
| Cereals | 95.3% | 95.1-99.8% | 100.0% | 100.0% |
| White roots and tubers | 44.0% | 20.8-65.2% | 42.9% | 99.3% |
| Vegetables | 48.6% | 78.9-93.8% | 100.0% | 100.0% |
| Fruits | 14.9% | 10.6-54.4% | 95.0% | 65.7% |
| Meat and poultry | 26.2% | 22.7-70.8% | 46.4% | 12.1% |
| Eggs | 11.3% | 4.9-50.5% | 75.7% | 56.4% |
| Fish and seafood | 0.9% | 0.1-2.6% | 0.0% | 0.0% |
| Pulses/legumes/nuts | 66.4% | 71.9-92.8% | 97.9% | 86.4% |
| Dairy products | 38.3% | 27.2-62.3% | 40.7% | 60.7% |
| Oil and fat | 72.9% | 69.3-99.3% | 100.0% | 100.0% |
| Sweets | 32.1% | 28.5-84.2% | 69.3% | 73.6% |
| Spices, condiments and beverages | 93.2% | N.A | 100.0% | 100.0% |

*[a] Coates and Galante (2014) and [b] Workicho et al. 2016.*

### 5.4.3 Dietary adequacy

Compared with the national average reported by CSA and WFP (2014) where 10% of the population exhibits a 'poor' dietary adequacy, the households of Yayu perform relatively well, since no 'poor' dietary adequacy was identified in either season,, even in the severely food insecure shortage season. This indicates that the type of food security in Yayu is rather different from a mere food shortage. Yayu people use different leaves, roots and tuber crops to cope with seasonal shortages, which maintain the overall dietary adequacy of the households. However, 10.1% of the target children and 9.2% of the women exhibit a borderline nutritional adequacy performance. This implies that there is a risk of nutrition insecurity in a considerable share of the households.

The study detected non-significant variation in the dietary adequacy across the target groups across seasons. In contrast, Hirvonen et al. (2016) reported a significant seasonal variation in the overall dietary intake of 27,835 households in all regions of Ethiopia. Ngala et al. (2015) also reported a significant seasonal variation trend in both target groups in Kenya.  This disparity indicates that the seasonal trend of dietary intake in Yayu has little effect on the overall dietary adequacy of the people.

In the weekly consumption of the studied nutrients, heme iron is the most critical nutrient, as the consumption of food items rich in heme iron was notably low in both target groups. The situation was aggravated in the shortage season, opening the possibility of a chronic deficiency. However, this problem is not exclusive to Yayu, as it is reported country wide (CSA and WFP 2014). Also interesting is the decrease in the consumption of vitamin-A-rich foods in the surplus season due to the reduction in the consumption of dark green vegetables, which in Yayu are considered as ‘shortage season’ food. In addition, the consumption of dairy products was higher in the shortage seasons, concurrent with the higher availability of forage for the cattle at the beginning of the rainy season also contributing to the increased vitamin-A intake, especially for the NBF children under 5 years.

The daily dietary adequacy assessment for NBF children under 5 years (38.6%) and WAR (52.1%) showed low adequacy irrespective of season. This indicates that the daily trend differs from the weekly. In addition, the mean IDDS value of all target groups in both seasons was less than 6 food groups, which confirms that the majority of the Yayu households consume relatively fewer food groups per day. Kennedy et al. (2011) confirm that IDDS below 6 food groups indicates a daily dietary inadequacy. Based on this, at least 76.4% of the children under 5 years and 75% of the WRA in Yayu are not getting an adequate daily diet. However, there is an improvement in the weekly consumption trends discussed above, which shows that the majority of the samples are within the ‘acceptable’ FCS category (Figure 5-2 and 5-3).

The total mean IDDS values of both target groups in Yayu range from 3.6 to 3.9 that were lower and higher, respectively, compared to results from other areas of the country. Desalegn et al. (2017), who assessed 379 mother-child pairs in Wolayita, southern Ethiopia, found a mean dietary diversity of 2.37, which is lower than the values in the present study. In contrast, Worku et al. (2017) evaluated the daily dietary diversity of 639 adolescent women of the Gurage zone of south-western Ethiopia and observed a mean value of 4.69, which is higher than that in Yayu. The national mean values reported by Gebremedhin and Enquselassie (2011) and Coates et al. (2007b) were 4.01 and 4.6, respectively, and thus higher than those of the present study. However, the difference may due to the dissimilarities in the number of food groups considered, i.e. 12 in the national level studies against 9 in this study. In addition, Gebremedhin and Enquselassie (2011) considered only WRA. All in all, a consistent national value below 6 food groups recommends improving the daily dietary diversity of these groups.

Regarding the consumption trend of the three specific nutrients assessed, the daily consumption of heme-iron-rich foods was critically low, as also in the weekly trend (Figure 5-2). This relates to the lack of animal-based food rich in iron, although the compensation of non-heme iron in plant food, such as *Eragrostis tef*, was considered. In general, the prevalence of heme iron deficiency in Yayu is higher than that reported for the national by Gebremedhin and Enquselassie (2011), who state that about 85% of the WRA were not consuming even one iron-rich food group daily, whereas in Yayu values reached up to 96.4% during the shortage season. These results are consistent with the national average daily intake of iron for women estimated as 12.9% (EPHI 2013), and this highlights a concomitant deficiency of heme iron in Yayu.

Regarding the daily protein intake, the proportion of WRA who do not consume protein-rich foods in Yayu ranged from 7.1% to 21.4%, which was lower than the national average of 51.1% (EPHI 2013). Similarly, the share of NBF children under 5 years who do not consume the recommended daily portion of protein in Yayu, i.e. a maximum of 19% in the shortage season, was lower than the national value for the children (6-23 months) (51.5%)(EPHI 2013). This indicates that the communities in Yayu show a better daily protein consumption trend than most areas of the country, which may be due to the relatively higher legume consumption pattern discussed above.

The share of WRA who did not consume at least one vitamin-A-rich food group per day in Yayu (max. 45.7% in the surplus season) (Figure 5-3) was considerably low compared to the national level (82%) (EPHI 2013). The share of NBF children under 5 years with access to daily vitamin-A-rich food including those who receive supplement was 53% on the national level (ICF International 2012), which is lower than in Yayu (min. 66.4% in the surplus season) (Figure 5-3). In contrast, the daily consumption of foods rich in vitamin A was low during the shortage season. This was due to an increased consumption of dark green vegetables and dairy products during this period. Both types of food are abundantly available during the shortage period because of the naturally synchronized mating season and availability of sufficiently large pasture areas due to high rainfall in the shortage season. Generally, the daily consumption of the three nutrients in Yayu are considered better than the national values, though there is still a considerable share of nutritionally insecure households.

A correlation between the weekly and daily dietary diversity intake scores and the settlement history and ethnicity of the households was identified, which are both proxies of the knowledge on the type, importance, and management of the flora in the area. This implies that the indigenous knowledge existing in the area has a positive contribution to the dietary habits of the households, specifically to the management and utilization of the shortage season foods, and emphasizes their importance for further studies, which need to consider the interfaces between social, cultural, nutritional and ecological parameters of Yayu as entry points to address FNS.

### 5.4.4 Nutritional status

Though the area is considered food secure (section 3.1), the anthropometric indicators of NBF children under 5 years showed that still part of the community is not fully nutritionally secure, especially during the shortage season. The lowest value (3.9% wasted children) was observed during the shortage season. However, the values are lower than the national average (about 9%) and much lower than that of west Gojam (14.8%), another food-secure area. Nevertheless, the values in this study are in the ‘low prevalence’ category of the WHO cut-off points prepared for public health significance (WHO 1995). On the other hand, the prevalence of stunting (38.2%) was equivalent to the national levels reported in the health survey of 2016 (38.4%) and regarded as 'high prevalence' (30-39%) (WHO 1995) (Table 5-11).

Table 5-11. Prevalence of wasted, underweight and stunted NBF children under 5 years (national level, west Gojam zone, Yayu).

| Prevalence (%) | National | | West Gojam | Yayu | |
|---|---|---|---|---|---|
| | 2011[a] | 2016[b] | 2009[c] | Surplus | Shortage |
| Wasting | 9.7% | 9.9% | 14.8% | 2.9% | 3.9% |
| Underweight | 28.7% | 23.6% | 49.2% | 5.0% | 10.0% |
| Stunting | 44.4% | 38.4% | 43.2% | 17.9% | 38.2% |

*[a] CSA and ICF International 2012; [b] CSA and ICF International 2016; [c] Teshome et al 2009*

The average distribution of anthropometric indices during the two seasons compared with the WHO standards (Figure 5-4 A, B and C) shows that the weight for age and the height for age z-score distribution of NBF children under 5 years in both seasons were skewed to the left of the WHO standards, and were more pronounced during the shortage season (Figure 5-4 B and C). In contrast, the weight to height distribution shows a good fit with WHO standards (Figure 5-4A). Although most of Yayu is labeled food secured (section 3.1), the computed values show the presence of stunting, wasting and underweight in NBF children under 5 years (Table 5-7) that, coupled with the distribution of z-scores, suggests the existence of hidden hunger in the area.

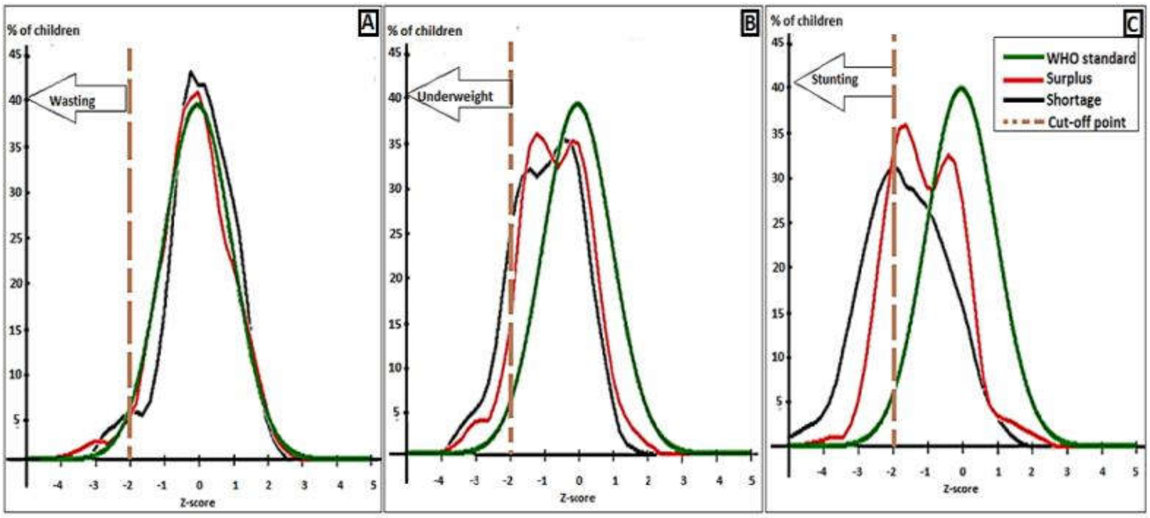

Figure 5-4. Distribution of anthropometric indicators of NBF children under 5 years in Yayu compared to global WHO references across seasons. A. weight for height. B. weight for age. C. height for age

In the case of WRA, the anthropometric indicators show that 8.6% in Yayu were malnourished or moderately/severely thin. Still, the value is lower than the national value (27%) (CSA and ICF International 2012). But the prevalence of malnourished WRA increased during the shortage season to 13.6%, which is defined by the WHO as a ‘poor situation’, which is a warning sign suggesting monitoring the community (WHO 1995). The detected values coupled with dietary pattern and adequacy proportion indicate the possibility of hidden hunger of the WRA in the area.

## 5.5 Conclusions

The findings indicate that smallholding farming communities of Yayu can be mostly considered hunger free. Referring to the HFIAS-based food and nutrition security assessment, some households face moderate to severe food insecurity, which relates to the access to food regardless of the season. Regarding the utilization pillar, the area provides sufficient energy to the majority of households (>95%) and energy-rich staples in both seasons. With respect to the adequacy of consumed nutrients, again the majority of the households exceed the acceptable consumption threshold.

The consumption of protein is common with few exceptions. The dietary diversity increases during the shortage season regardless of the amount of food available, due to the inclusion of milk and other shortage-time food in the diets. The consumption of vitamin-A is extensive but only in the shortage season, as people eat more dark green vegetables and dairy products, and tend to shift to cereal-dominated diets during the surplus season. However, a chronic iron deficiency is possible as a consequence of the very low trend in the consumption of heme-iron-rich food, especially during the shortage season. The compensation of such deficiency could be possible with regular consumption of non-heme-iron-rich food like *Eragrostis tef*.

The observed levels of wasting, underweight and stunting in NBF children under 5 years, and malnourishment in WRA suggest the existence of certain forms of hidden hunger in scattered households, as the definition of food and nutrition security stresses on the availability of quality food required for a healthy life for all people at all times. The findings of the present study indicate seasonal and content-wise food shortcomings in the households' access to and utilization of food. It can be concluded that Yayu cannot be considered fully food secure, though the situation is much better than in most of the country.

Further studies on seasonal and nutritional deficits through assessing the available resources, utilization trends, farming systems, and related factors are recommended. Besides, as this study is based on a 'proxy approach' to determine the food and nutritional security, which has intrinsic limitations, direct and more accurate methods such as blood analyses would provide more precise information on people's food and nutritional security.

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# 6 ASSOCIATIONS BETWEEN ATTRIBUTES OF AGROFORESTRY PRACTICES AND THE FOOD AND NUTRITION SECURITY INDICATORS OF SMALLHOLDING FARMING HOUSEHOLDS OF YAYU, SOUTH-WESTERN ETHIOPIA

## 6.1 Introduction

Under the current poor technology usage and rapidly increasing population, which increases the demand for agricultural food and non-food products, the burden on arable land of the sub-Saharan agrarian developing countries is intensifying, and the productivity of farming systems is expected to decline at an excessively faster rate (Dixon et al. 2001; Pingali et al. 2001; Mozumdar 2012; Jayne et al. 2014). These are challenges that are fueled even further by the human-induced challenge of climate change (FAO 2009c). Under such scenarios, climate-smart multipurpose farming systems such as agroforestry are gaining attention due to their potential in addressing food insecurity and supplying other non-food agricultural products while maintaining environmental integrity (Bogdanski 2012; Mbow et al. 2014; Catacutan et al. 2017). This is particularly true for the rural poor in agrarian developing countries, where improving people’s food and nutrition conditions and livelihoods is a fundamental goal (Duguma et al. 2001; Ickowitz et al. 2013 and Mbow et al. 2014).

Many reports have revealed how agroforestry contributes to the four pillars of food and nutrition security (FNS). Researchers indicate that agroforestry can contribute to food availability, directly via the production of food from the perennial component(s), and/or indirectly through the enhancement of the production of annual crops and/or animal/insect component(s) (Jamnadass et al. 2013; Sarvade et al. 2014), e.g. the *enset*-coffee homegardens of the Sidama and Gedeo communities in southern Ethiopia that include the perennial *Ensete ventricosum*, which serves as staple food for about 15 million people in the region (Abebe 2013). More frequently, and beside the direct provision of edible products, agroforestry can enhance the yields of other food crop component(s) of the system, e.g. in Sudan, *Faidherbia albida* has increased the harvests of surrounding cereals and groundnut up to 200% (Fadl and El sheikh 2010).

Concerning their contribution to food access, some agroforestry systems/practices may focus on the production of highly valuable cash products, e.g. *Coffea arabica* and *Theobroma cacao* (Duguma et al. 2001; Gole et al. 2009; Abebe 2013). But in the majority of cases, the array of merchantable agroforestry products is wide including fruit, stimulants, spices, wood, resins, etc., which can also generate a considerable amount of cash through selling. For instance, in Bushbuckridge, South Africa, farmers sell the fruit Marula (*Sclerocarya birrea*), which is the main component of a valuable cream liquor, to generate cash for their households (Shackleton 2004).

In the same fashion, the contribution of agroforestry toward the food utilization pillar is highlighted by different researchers. Increasing and diversifying the consumption of fruits, vegetables, and animal products is reported to be the most affordable and sustainable approach to abate micronutrient deficiency (Thompson and Amoroso 2010; Susila et al. 2012). Mbow et al. (2014) identified agroforestry as a good source of micronutrients, mostly in form of fruits, nuts, and leafy vegetables. Using data collected from 21 African countries during the period 2003–2011, Ickowitz et al. (2013) found a strong correlation between tree cover and dietary diversity. Abebe (2005) and Méndez et al. (2001) observed a great diversity in homegardens, mainly due to the diversity of vegetables, fruits, and spices, with nutrient-rich food products. A number of reports state that the inclusion of fodder and forage from trees and shrubs into the animal feed enhanced animal production, significantly improving the households' access to animal-based foods (Dixon et al. 2010; Wambugu et al. 2011; Franzel et al. 2013; Dawson et al., 2014; Sarvade et al., 2014). In general, agroforestry improves the availability of diversified foods, which in most cases compensate the nutrients lacking in starchy staple-based diets.

The fourth pillar of FNS, food stability, which is normally achieved when a relative stability of the previous three pillars is attained, is observed in many agroforestry practices (AFP) where species diversity exists. In this case, the presence of more than one edible species, each with different phenology and different harvesting calendar, results in a consistent availability of foods across the year. This is key for most agrarian regions of the developing world, which tend to experience seasons of both food surplus and food shortage. For example, the Konso community in southern Ethiopia cultivates *Moringa stenopetala* in diverse agroforestry arrangements, whose main function is filling a gap in the annual food supply (Förch, 2003). Similarly, *Vitellaria paradoxa* and *Sclerocarya birrea*, the traditional components of agroforestry parklands, are reported as potential sources of food of local communities during droughts and crop failure in several parts of Africa (Maranz et al., 2004; Mojeremane and Tshwenyane, 2004; Jamnadass et al., 2013).

As seen in many reports, the contribution of agroforestry to households' FNS are more general and qualitative than specific and empirical. In contrast, studies on other farming systems report quantitative impacts between the characteristics of the specific farming system and a specific pillar or indicator of FNS. For instance, Walton (2012) conducted a study on the association between different attributes of a dairy farm of a smallholding household in Kenya with the respective FNS indicator values, and captured a significant association between the farm characteristics and household's FNS attributes. Jones et al. (2014) investigated the association between different farm characteristics of smallholding farming households of Malawi with different FNS indicators, and revealed a relationship between farm diversity and diet diversity. Such studies are important and show the effective entry point for future interventions to address FNS, however, they are hardly available with respect to AFP.

On the one hand, agroforestry is a generic term referring to a diversity of tree-based farming systems, which exhibit a wide variation in composition, structure, function, purpose of management, and therefore in the impact on the livelihood performance and the environment. On the other hand, FNS is a multidimensional concept. Hence, the contribution of agroforestry to household food security is not often straightforward. The empirical evidence on how different aspects of AFP are related to different aspects of the households are rare. Aiming to narrow this gap, the present study attempts to uncover the relation between selected attributes of AFP of smallholding farming households in the Yayu

Biosphere Reserve area located in south-western Ethiopia (section 3.1) with their respective FNS indicators. The specific objectives were:

- To determine the association between the identified AFP and their prominent features and the FNS status scores/indices of smallholding farming households of Yayu.
- To determine the association between the types of floristic and structural attributes of AFP and the FNS status scores/indices of smallholding farming households of Yayu.
- To determine the association between the utilization, edibility and marketability attributes of the AFP and FNS status scores/indices of smallholding farming households of Yayu.

## 6.2 Material and methods

### 6.2.1 Sampling

As this research is part of a bigger study that examined the role of agroforestry in the FNS of smallholding farmers in Yayu, the sampled households were the same as previously assessed for AFP. Out of the initial 300 households selected from 8 *kebele*[6] (section 4.2.1), a subset of 140 households where sensitive groups existed was considered (section 5.2.1). The target groups were NBF children under 5 years, and women at reproductive age (WRA) (15-45 years), generally the mother of the considered child. In a case where more than one child existed, the youngest was chosen; in case of twins, a lottery method was applied (Mulu and Mengistie, 2017).

### 6.2.2 Data collection

Two data sets, i.e. the household's AFP and FNS attributes were collected separately. Data were collected between December 2014 and February 2015 by interviewing the head of the sample household and through field observation. The characterization of the AFP included data such as type and size of practice, proximity to market and forest, existing species, the arrangement of species, plant utilities, and marketability of the products, and were collected separately. Species identification was accompanied by direct observation of the household plots. In addition, data on the type of and size of animal components managed by the households were collected (section 4.2.2).

Data on the FNS attributes were collected between December 2014 and August 2016 in order to cover the food surplus and shortage seasons. The surplus season refers to the post-harvest period of coffee and cereals between June and September, while the pre-harvesting period from January to March is regarded as the shortage season (section 3.1). Data included household responses to food security questions, dietary intake history and anthropometric measurements, which were ultimately used to determine the households' FNS status and dietary adequacy.

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[6] *Kebele* is the smallest administrative unit of Ethiopia, population reaching up to 4,000 peoples

Household FNS status was obtained by computing the scores of two indicators, i.e. the Household Food Insecurity Access Scale (HFIAS) (Coates et al. 2007a) and the Household Dietary Diversity Score (HDDS) (Swindale and Bilinsky, 2006). Then, 24-hour and 7-day dietary intake history data were used to generate the Individual Dietary Diversity Score (IDDS) (Kennedy et al. 2010) of the target individuals of the households, i.e. NBF children under 5 years and the WRA.

Anthropometric data on the age, weight, and height of the target children and non-pregnant women was measured. Electronic scales precise to 100 g, and wooden collapsible length/height measuring devices precise to 1 mm were used. The age of the children was captured in years and months and of women in years. The anthropometric measurements were used to determine the weight to height z-score (WHZ), weight to age z-score (WAZ), and height to age z-score (HAZ) of the target children (WHO, 2006), and the body mass index of the (BMI) of the target women (WHO, 1999; FANTA, 2016) (section 5.2.2).

### 6.2.3 Data analysis

The agroforestry data set (Chapter 4) was used to generate four major attributes, i.e. type of AFP run by a household, its prominent features, floristic characterization and utilization potential. Three major AFP were identified, i.e. homegarden (HG), multistorey-coffee-system (MCS) and multipurpose-trees-on-farmland (MTF) and, based on the practices applied, 7 types of AFP households were identified, i.e. those with (1) only MTF, (2) only MCS, (3) only HG, (4) MTF and MCS, (5) MTF and HG, (6) MCS and HG, and (7) all forms of AFP. The second attribute of the prominent features included size and location of the plots of each AFP. Location refers to the relative distance of the household to markets and the forest area. The third attribute, floristic characterization, includes the number of species, herbs, shrubs, trees, native species, exotic species, and storeys per plot. Finally, under the utilization potential of AFP, the use types, species richness of 'total edible' plants, species richness of 'active food' crops, and species richness of 'actively-marketable' crops per plot were considered. In this study, the total edible species represents all species where at least one of the parts can be safely consumed by the local people, whereas the 'active food' crops represent species primarily cultivated for food, both main and supplementary foods (section 4.2.2). The ‘actively-marketable’ species group refers to the species where products were either mentioned as a cash crop by at least one sample household or observed at the local markets (section 4.2.2). The richness of each of these groups was determined using Menhinick's index (Equation 5.1) (Magurran, 1988).

Finally, the value of each of these variables was subjected to one-way ANOM and Pearson correlation to analyze the FNS attributes (Chapter 5); Minitab 17.0 and Statistica 7.1 software were used.

## 6.3 Results

### 6.3.1 Combinations of agroforestry practices versus food and nutrition security scores/indices

The one-way results of the ANOM analysis performed on the HFIAS and HDDS scores of the household against different combinations of AFP is presented in Figure 6-1. Only households with all three forms of AFP showed significantly lower HFIAS during the shortage and surplus season at α=0.05, whereas households with only MCS were found to have significantly higher HFIAS (Figure 6-1. A and B).

In contrast, the households with all AFP showed significantly higher HDDS at α=0.05 only during the shortage season (Figure 6-1. C and D). Regarding the relation between IDDS and the AFP, a significant variation was observed only in the shortage season. Households managing all AFP had a significantly higher dietary diversity both for children and women at α=0.05 (Figure 6-2).

Among the anthropometric nutritional status indicators for the NBF children under 5 years and WRA, only WHZ and WAZ had a significant variation across the 7 types of AFP combinations, so only these variables are presented (Figure 6-3). The households with all three AFP show significantly higher WAZ and WHZ in both the surplus and shortage seasons at α=0.05. In addition, those households with only HG scored significantly (α=0.05) lower WHZ in both seasons (Figure 6-3 B).

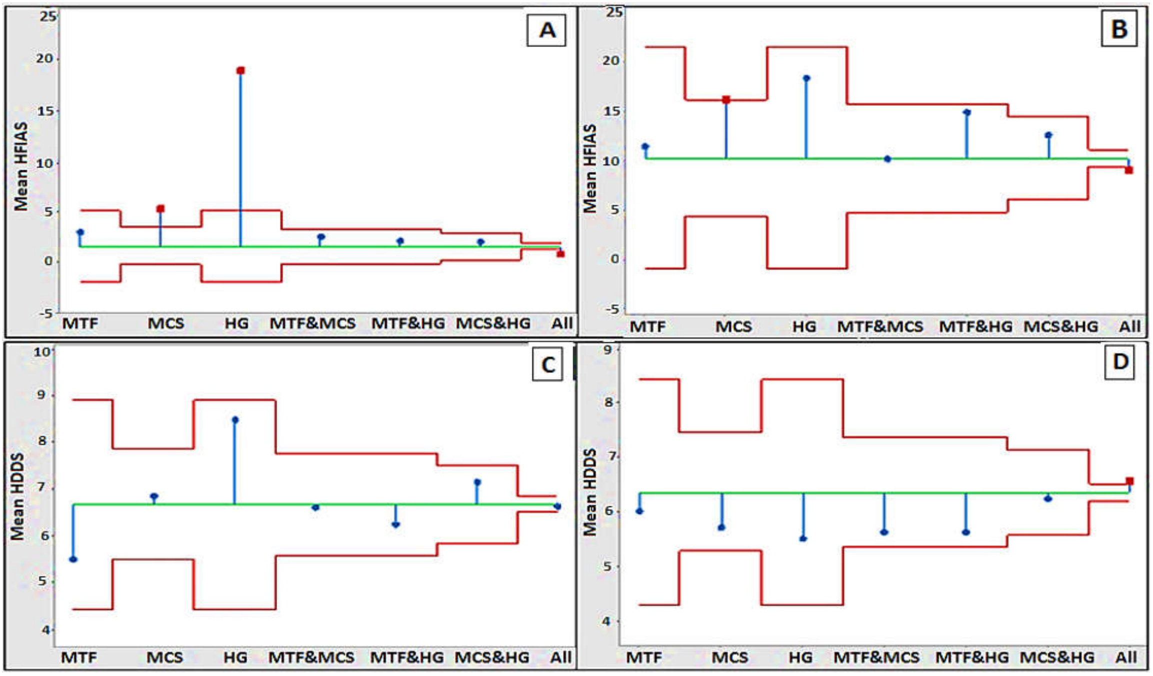


Figure 6-1. One-way ANOM across agroforestry practice combinations (α=0.05). A. HFIAS shortage season. B. HFIAS surplus season. C. HDDS shortage season. D. HDDS surplus season.

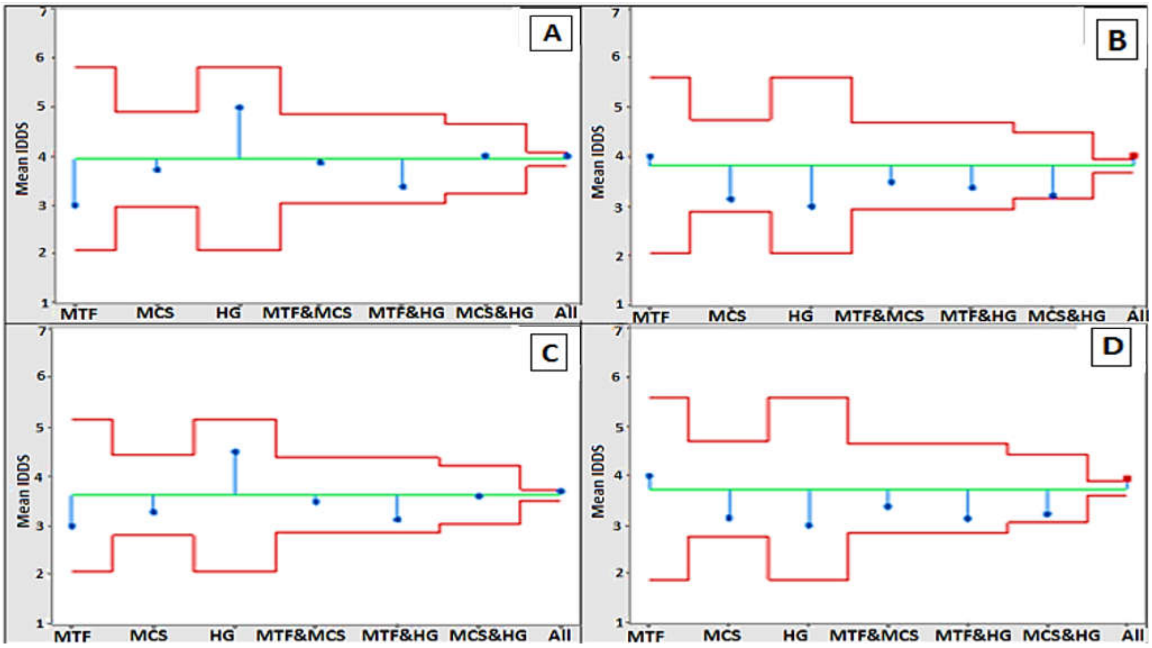


Figure 6-2. One-way ANOM of IDDS across 7 agroforestry practice combinations (α=0.05). A: NBF children <5 years in surplus season. B: NBF children <5 years in shortage season. C: WRA in surplus season. D: WRA in shortage season.

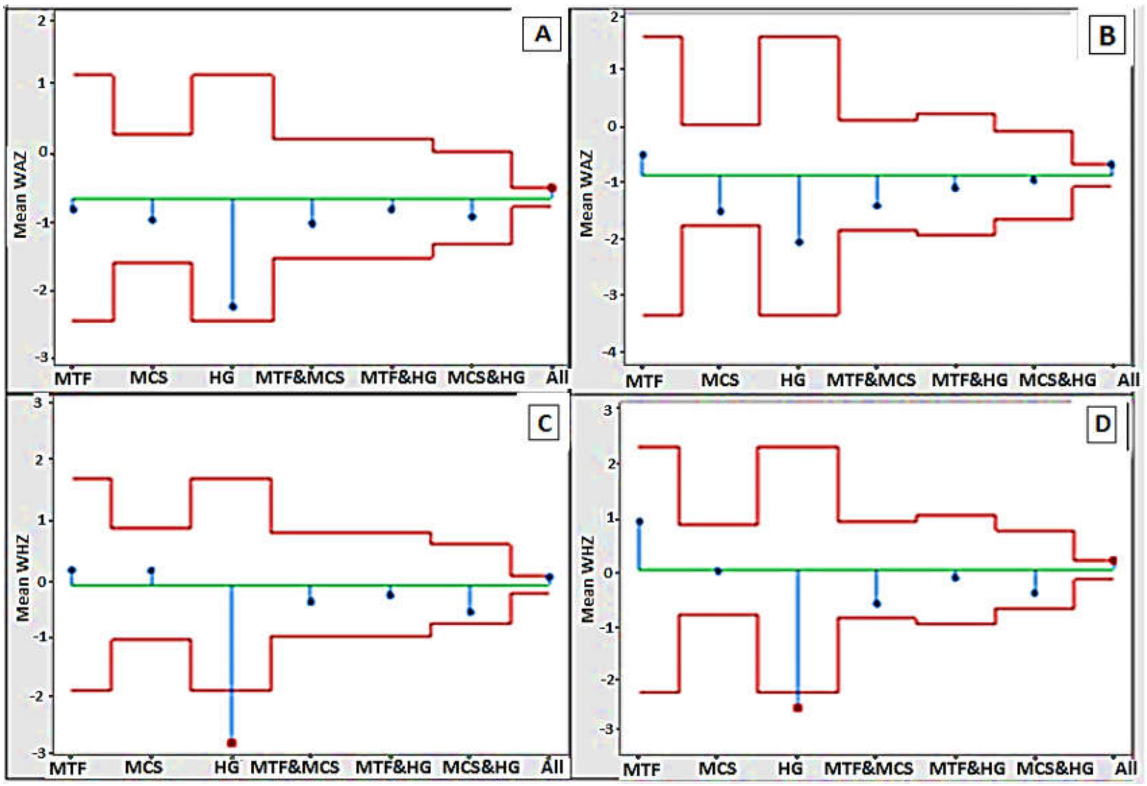


Figure 6-3 One-way ANOM across agroforestry practice combinations (α=0.05). A: WAZ in surplus season. B: WAZ in shortage season. C: WHZ surplus in season. D: WHZ in shortage season.

### 6.3.2 Size and proximity attributes of agroforestry practices versus food and nutrition security scores/indices

The analysis reveals that there is a significant association between the AFP characteristics and some FNS indices of the households. Regarding HFIAS, the highest association was observed during the shortage season with the MCS plot size (r=-0.68), the HDDS with the size of HG plots during shortage season, and the IDDS with the plot size of all AFP during the shortage season. In all seasons, HFIAS had a negative association with plot size and proximity to forest. In reference to the markets, the relative location of all AFP was significantly correlated with HFIAS and HDDS in both seasons. The size of HG was significantly correlated with WAZ in both seasons. The plot size of MCS was significantly correlated with WAZ and HAZ in both seasons (0.24 ≤r≥ 0.30). WHZ only correlated with HG plot size in the surplus season. Similarly, the BMI of WRA were only associated with HG size and only in the shortage season (Table 6-1).

Table 6-1. Pearson correlation coefficient among AFP plot size and proximities against food and nutrition security status scores of two seasons in Yayu.

| Attribute | AFP | Season | Household | | NBF children <5 yrs. | | | | WRA | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | HFIAS | HDDS | IDDS | WAZ | HAZ | WHZ | IDDS | BMI |
| Plot size | HG | Surplus | -0.24$^{**}$ | 0.15 | 0.11 | 0.23$^{**}$ | 0.14 | 0.21$^{*}$ | 0.14 | 0.09 |
| | | Shortage | -0.41$^{**}$ | 0.45$^{**}$ | 0.42$^{**}$ | 0.33$^{**}$ | 0.26$^{**}$ | 0.21 | 0.37$^{**}$ | 0.21$^{*}$ |
| | MCS | Surplus | -0.37$^{**}$ | 0.25$^{**}$ | 0.30$^{**}$ | 0.26$^{**}$ | 0.28$^{**}$ | 0.14 | 0.22 | -0.07 |
| | | Shortage | -0.68$^{**}$ | 0.42$^{**}$ | 0.34$^{**}$ | 0.30$^{**}$ | 0.24$^{*}$ | 0.19 | 0.30$^{**}$ | -0.05 |
| | MTF | Surplus | -0.40$^{**}$ | 0.12 | 0.28$^{**}$ | 0.18$^{*}$ | 0.22$^{**}$ | 0.08 | 0.28$^{**}$ | 0.02 |
| | | Shortage | -0.57$^{**}$ | 0.26$^{**}$ | 0.41$^{**}$ | 0.27$^{*}$ | 0.27$^{*}$ | 0.12 | 0.41$^{**}$ | 0.12 |
| Proximity to market | HG | Surplus | 0.13 | -0.32$^{**}$ | -0.24$^{**}$ | -0.05 | -0.12 | 0.05 | -0.26$^{**}$ | 0.06 |
| | | Shortage | 0.38$^{**}$ | -0.25$^{**}$ | -0.11 | -0.16 | -0.18 | 0.01 | -0.11 | 0.08 |
| | MCS | Surplus | 0.25$^{**}$ | -0.32$^{**}$ | -0.2$^{*}$ | -0.16 | -0.21$^{*}$ | -0.04 | -0.2$^{*}$ | 0.06 |
| | | Shortage | 0.38$^{**}$ | -0.24$^{**}$ | -0.14 | -0.27$^{*}$ | -0.28$^{*}$ | -0.05 | -0.15 | 0.07 |
| | MTF | Surplus | 0.29$^{**}$ | -0.32$^{**}$ | -0.26$^{**}$ | -0.16 | -0.20$^{*}$ | -0.05 | -0.29$^{**}$ | 0.10 |
| | | Shortage | 0.44$^{**}$ | -0.26$^{**}$ | -0.19$^{*}$ | -0.24 | -0.27$^{*}$ | -0.04 | -0.19$^{*}$ | 0.12 |
| Proximity to forest | HG | Surplus | -0.15 | -0.12 | 0.05 | -0.02 | 0.05 | -0.06 | 0.09 | -0.13 |
| | | Shortage | -0.12 | 0.17 | 0.21$^{*}$ | 0.18 | 0.10 | 0.16 | 0.19$^{*}$ | 0.01 |
| | MCS | Surplus | -0.27$^{**}$ | -0.1 | 0.08 | 0.08 | 0.14 | -0.01 | 0.15 | -0.13 |
| | | Shortage | -0.22$^{*}$ | 0.22$^{*}$ | 0.24$^{**}$ | 0.31$^{**}$ | 0.25$^{*}$ | 0.22 | 0.22$^{*}$ | 0.03 |
| | MTF | Surplus | -0.14 | -0.09 | 0.06 | 0.03 | 0.08 | -0.04 | 0.1 | -0.13 |
| | | Shortage | -0.08 | 0.15 | 0.17 | 0.23 | 0.15 | 0.18 | 0.15 | -0.05 |

**significant at $p<0.05$;   ** significant at $p<0.01$; negative correlation coefficient shows direction of association*

### 6.3.3 Floristic and structural attributes of agroforestry practices versus food and nutrition security scores/indices

Among the floristic and structural attributes of AFP, the number of species and storeys per plot were contrasted with the FNS status of the households (Table 6-2). Both attributes had a significant negative correlation with HFIAS (-0.21≤ r ≥-0.41) in both seasons, while with HDDS (0.20≤ r ≥0.31) in the shortage season only. There was no significant correlation of IDDS of both target groups during the surplus season, but the number of species in MCS was correlated during the shortage season.  In addition to the number of species in MTF, the number of storeys significantly correlated with the IDDS of NBF children under 5 years.

Cross analyzing their association with anthropometric measurements, the number of species in MCS significantly correlated with the WAZ and the WHZ of the children during the surplus season. The number of storeys per HG shows a significant relationship with the HAZ of the children in both seasons, and is also significantly correlated with WAZ during the shortage season. No correlation was detected between the floristic and structural attributes and the BMI of the WRA.

Table 6-2. Pearson correlation coefficient among floristic and structural attributes of three agroforestry practices against different food and nutrition security status scores of two seasons in Yayu.

| **Attribute** | **AFP** | **Season** | **Household** | | **NBF children <5yrs** | | | | **WRA** | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | **HFIAS** | **HDDS** | **IDDS** | **WAZ** | **HAZ** | **WHZ** | **IDDS** | **BMI** |
| Total no. Species | HG | Surplus | -0.25$^{*}$ | 0.13 | 0.11 | 0.1 | 0.17 | 0.01 | 0.16 | 0.08 |
| | | Shortage | -0.21$^{*}$ | 0.20$^{*}$ | 0.07 | 0.18 | 0.24 | 0.01 | 0.08 | 0.01 |
| | MCS | Surplus | -0.36$^{**}$ | 0.15 | 0.16 | 0.24$^{*}$ | 0.11 | 0.25$^{*}$ | 0.12 | 0.13 |
| | | Shortage | -0.41$^{**}$ | 0.31$^{**}$ | 0.26$^{*}$ | 0.21 | 0.11 | 0.17 | 0.27$^{**}$ | 0.17 |
| | MTF | Surplus | -0.31$^{**}$ | -0.13 | -0.01 | 0.16 | 0.08 | 0.17 | 0.03 | 0.05 |
| | | Shortage | -0.32$^{**}$ | 0.26$^{*}$ | 0.22$^{*}$ | 0.26 | 0.17 | 0.23 | 0.17 | 0.02 |
| No. storey | HG | Surplus | -0.30$^{**}$ | 0.11 | 0.13 | 0.16 | 0.22$^{*}$ | 0.067 | 0.15 | 0.07 |
| | | Shortage | -0.21$^{*}$ | 0.27$^{**}$ | 0.15 | 0.29$^{*}$ | 0.29$^{*}$ | 0.13 | 0.16 | -0.01 |
| | MCS | Surplus | -0.40$^{**}$ | 0.07 | 0.14 | 0.15 | 0.06 | 0.15 | 0.12 | 0.05 |
| | | Shortage | -0.35$^{**}$ | 0.27$^{*}$ | 0.13 | 0.1 | -0.01 | 0.15 | 0.16 | 0.1 |
| | MTF | Surplus | -0.40$^{**}$ | -0.20 | -0.07 | 0.18 | 0.06 | 0.22$^{*}$ | -0.02 | 0.1 |
| | | Shortage | -0.38$^{**}$ | 0.26$^{*}$ | 0.30$^{**}$ | 0.19 | 0.06 | 0.24 | 0.24$^{*}$ | 0.07 |

**significant at p<0.05;   ** significant at p<0.01; negative correlation coefficient show direction of association*

### 6.3.4 Utilization, edibility and marketability of species of agroforestry practices versus food and nutrition security scores/indices

The utilities of all AFP had a significant correlation with HFIAS in both seasons, and with HDDS in the shortage season (Table 6-3). The IDDS of both target groups showed a significant correlation with the number of utilities per plot of MCS and MTF during the shortage season. Regarding the anthropometric indices, the strongest association was observed between the number of utilities per HG and the HAZ of the NBF children under 5 years during the shortage season (Table 6-3).

Both edibility-related attributes, i.e. the total edible and ‘active food’ species richness, showed significant associations with HFIAS in both seasons, whereas the species richness of both attributes in the HG showed a correlation with the HDDS during the shortage season. Regarding the IDDS, the total edible and ‘active food’ species of MTF plots showed a significant correlation with both target groups during the shortage season. Both attributes of MTF showed significant correlations with the WAZ of the children in both seasons. Both attributes of HG showed a significant correlation with HAZ of the children only during the shortage season (Table 6-3).

Regarding the marketability attributes of AFP, the richness of ‘actively-marketed’ species per plot of all practices show significant correlations with HFIAS in both seasons except in MCS plots. HDDS was only correlated with the species richness of ‘actively marketed’ species in HG plots in the shortage season.

None of the four attributes of AFP show a significant correlation with the BMI of WRA (Table 6-3).

Table 6-3. Pearson correlation coefficient among use, edibility and marketability attributes of three agroforestry practices against different food and nutrition security status scores of two seasons in Yayu.

| Attribute | AFP | Season | Household | | NBF children <5 yrs. | | | | WRA | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | HFIAS | HDDS | IDDS | WAZ | HAZ | WHZ | IDDS | BMI |
| No. of use type | HG | Surplus | -0.28** | 0.04 | 0.01 | 0.16 | 0.23* | 0.04 | 0.06 | 0.12 |
| | | Shortage | -0.22* | 0.28** | 0.18 | 0.30* | 0.31* | 0.14 | 0.18 | 0.02 |
| | MCS | Surplus | -0.44** | 0.05 | 0.13 | 0.21* | 0.07 | 0.23* | 0.13 | 0.13 |
| | | Shortage | -0.40** | 0.32** | 0.25* | 0.22* | 0.11 | 0.21 | 0.28** | 0.19 |
| | MTF | Surplus | -0.44** | -0.18 | -0.03 | 0.19 | 0.11 | 0.17 | 0.02 | 0.11 |
| | | Shortage | -0.37** | 0.32** | 0.34** | 0.22 | 0.12 | 0.22 | 0.29** | 0.07 |
| Richness total edible | HG | Surplus | -0.27** | 0.15 | 0.17 | 0.09 | 0.19 | -0.03 | 0.20 | 0.10 |
| | | Shortage | -0.21* | 0.22* | 0.07 | 0.22 | 0.26* | 0.06 | 0.08 | 0.02 |
| | MCS | Surplus | -0.32** | 0.08 | 0.19 | 0.19 | 0.08 | 0.20 | 0.15 | 0.09 |
| | | Shortage | -0.27** | 0.19 | 0.14 | 0.07 | 0.02 | 0.07 | 0.16 | 0.08 |
| | MTF | Surplus | -0.38** | -0.18 | 0.01 | 0.25* | 0.15 | 0.24* | 0.05 | 0.14 |
| | | Shortage | -0.31** | 0.15 | 0.29** | 0.32* | 0.25 | 0.23 | 0.27* | 0.13 |
| Richness active food | HG | Surplus | -0.29** | 0.15 | 0.17 | 0.09 | 0.2 | -0.04 | 0.2 | 0.09 |
| | | Shortage | -0.22* | 0.24* | 0.08 | 0.22 | 0.26* | 0.06 | 0.08 | 0.03 |
| | MCS | Surplus | -0.05 | 0.04 | 0.11 | 0.07 | -0.04 | 0.14 | 0.10 | 0.16 |
| | | Shortage | -0.09 | 0.11 | 0.09 | 0.07 | -0.03 | 0.14 | 0.12 | 0.17 |
| | MTF | Surplus | -0.41** | -0.17 | 0.02 | 0.24* | 0.15 | 0.24* | 0.04 | 0.11 |
| | | Shortage | -0.35** | 0.10 | 0.29** | 0.26* | 0.26* | 0.13 | 0.29** | 0.13 |
| Richness actively-marketable | HG | Surplus | -0.30** | 0.16 | 0.22* | 0.10 | 0.19 | -0.02 | 0.25* | 0.09 |
| | | Shortage | -0.27** | 0.28** | 0.12 | 0.22* | 0.26* | 0.06 | 0.11 | 0.05 |
| | MCS | Surplus | -0.12 | 0.04 | 0.11 | 0.10 | -0.02 | 0.16 | 0.11 | 0.19 |
| | | Shortage | -0.11 | 0.13 | 0.12 | 0.11 | 0.00 | 0.17 | 0.16 | 0.19 |
| | MTF | Surplus | -0.43** | -0.13 | 0.00 | 0.21* | 0.11 | 0.22* | 0.03 | 0.09 |
| | | Shortage | -0.35** | 0.12 | 0.24* | 0.13 | 0.10 | 0.11 | 0.22* | 0.10 |

**significant at p<0.05;   ** significant at p<0.01; negative correlation coefficient showed the direction of the association*

## 6.4 Discussion

The results show that there was no single AFP with better a FSN of the households. Rather, the households with all three AFP show a better FNS status. As each AFP has a particular purpose, management and output, the missing of any of these will open a breach in a household’s ability to address all pillars of FSN. For instance, in Yayu the main food supply comes from MTF, and the cash from MCS. Households who have neither of these practices find it difficult to meet food security across the year. In most cases, the observed seasonal gap in food and cash supply is filled by the HG. Similar results were produced in a study performed in Myanmar, where there was a significant correlation between farm diversification with HFIAS and HDDS (Choa et al. 2016). Munyua and Wagara (2015) reported that farming system diversification has a positive impact on household FNS.

Among all AFP attributes considered, plot size was observed to exhibit the strongest association with most of the FNS indicators, because the land size is directly related with wealth and resources availability of the households. Wealth status has a strong association with the HFIAS, dietary habit and other FNS indicators (Chapter 5). A similar association between land holding size and FNS in Myanmar was reported by Rammohan (2014).

Another important attribute is the plot distance from markets and forest areas. Households with AFP plots located further from the markets exhibit higher HFIAS, i.e. are more food insecure than those placed near these, especially during the shortage season. This situation may also reduce the access to market foods, as the households are far from the supply, and also reduce the species richness of HG plots, which are the source of food and/or cash during the shortage season. The richness of total useful species, number of edible crops and marketable species are associated with their proximity to the markets (section 4.3.6). A similar influence of markets on the HG and FNS attributes of smallholders is also reported by Mellisse et al. (2017b).

Regarding the individual dietary diversity, the proximity to market had a limited association, except during the surplus season. In Yayu, coffee harvesting overlaps with the food surplus season (section 3.1). During this season, the dietary diversity of both target individuals had a significant association indicating that households with AFP near the market have a greater chance to diversify their diet through purchasing food at these markets. A study on 8230 smallholding farming households from four developing countries including Ethiopia revealed a positive relation with their proximity to markets (Qaim et al. 2015). However, during the shortage season, all households, regardless of their proximity to markets, have a similar dietary diversity. Due to the low cash availability, they are dependent on indigenous self-grown food crops like *Ensete ventricosum*, *Brassica oleracea*, and *Brassica carinata* (Chapter 4; key informant communication July, 2016). On the other hand, the households with AFP plots located far from the forest areas have better food security status than those near. This is explained by the locals as being due to the great crop damage caused by wild animals. As guarding costs are high, farmers are discouraged to produce annual crops up to the optimum level (section 4.4.5). In contrast, in Tanzania, a positive correlation among FNS indictors and proximity to the forest was found (Powel et al. 2011). This might be explained by the differences in the types of the production system and the dietary patterns of the two communities. In Yayu, farming households are highly dependent on cereals, which are equally available through self-production or purchasing from markets (Chapter 4 and 5), whereas the community considered in Tanzania highly relied on the indigenous vegetables, fruits and tubers collected from the forest (Powel et al. 2011).

The negative association between the total number of plant species in all AFP and the HFIAS of households implies that the contribution of each AFP is dependent on its floristic composition. This because the AFP plots with higher diversity or number of plant species have a better chance to provide either food or saleable products, which ultimately increase households' access to foods from the market. A similar finding was reported from Myanmar regarding the association between the species richness of farming plots and FNS status of smallholders (Choa et al. 2016). In Yayu, the number of species was only related to the dietary diversity of the households during the shortage season. This confirms the above-mentioned higher dependency of the households on the self-produced food only during the shortage season, while the marketed foods are important during the surplus season.

Households that gained a higher number of use and service types from their AFP had a better FNS status, i.e. lower HFIAS, than those who obtained fewer. Similarly, species richness of the 'active food' and 'actively-marketable' crop species was associated with HFIAS. A similar finding from farmers' HG in southern Ethiopia was reported by Mellisse et al. (2017b), while Remans et al. (2011) revealed a positive association among edible plant species diversity, food security and diet diversity of 170 smallholders in Malawi. This indicates that the multiple benefits from AFP contribute differently towards the four pillars of FNS.

In general, all AFP attributes have a negative and consistent association with HFIAS. This might due to the nature of the indicator, which includes sufficiency and psychological aspects (Coates et al. 2007a; Maxwell et al. 2013). Moreover, the relatively wider reference period of four weeks makes it a more stable attribute. Regarding HDDS and IDDS, AFP attributes showed an association only during the shortage season. This might be due to the dietary intake habit in Yayu that becomes less variable during the surplus season due to the tendency of the smallholders to rely on starch-dominated foods purchased from the market (Chapter 5).

On the other hand, there was seasonal variation of the association of agroforestry attributes with FNS indicators, specifically with HDDS and IDDS. The shortage season scores showed higher correlation values than the surplus season. This indicates an increase in the seasonal food insecurity in the area. During the surplus season, the majority of the households have similar access to similar types of food, whereas in the shortage season, there is a wider variation in the amount and type of foods. This agrees with the study by Savy et al. (2006) on women of rural Burkina Faso, and on NBF children under 5 years and WRA in rural Kenya by Ngala (2015).

In contrast, the attribute with lowest correlation with AFP attributes was the anthropometric indicator BMI of the WRA. This might be due to the nature of the indicator, as the BMI is influenced by multiple types of factors such as biological, socioeconomic, behavioral, dietary and health attributes related to the history of the individual (Tavani 1994). In the study of Savy et al. (2006) focusing on the impact of seasonal food shortage on the IDDS and BMI of 500 women from rural Burkina Faso, the anthropometric indicator was the attribute with the weakest association with socioeconomic characteristics of the households.

## 6.5 Conclusions

Food and nutritional security of smallholding farming households of Yayu were correlated with all the three types of AFP, namely HG, MCS, and MTF. No single AFP was associated with the overall FNS status of the households. In addition, plot size of each type of AFP had a positive influence on the FNS of the smallholders. The floristic composition and the number of utilities obtained from each type of AFP correlated with the FNS of the households.

All AFP attributes had a consistent association with the HFIAS. In the shortage season, IDDS correlated with the 'active food' species richness of the MTF plots. In addition, the correlation of the AFP attributes with the FNS indicators was more consistent during the shortage season. This confirms that the role of agroforestry in the seasonal food security of the area is significant and crucial.

An impact of markets on the overall dietary intake of the households during the surplus season was identified. This shows the importance of the market in shaping both the AFP and FNS attributes of the households.

In general, the association between agroforestry attributes and nutritional status indicators, specifically the anthropometric scores of the target household members, were weakly correlated, indicating the involvement of other factors in influencing the attributes.

# 7 NUTRITIONAL VALUE OF POTENTIALLY EDIBLE PLANTS SPECIES IN SHORTAGE SEASON IN YAYU, SOUTH-WESTERN ETHIOPIA

## 7.1 Introduction

The final objective of the present study is assessing the additional potential of the plant resources both within the AFP and the surrounding land use of Yayu for contributing to the FNS of the smallholding farming households. Hence, the nutritional potential of potentially edible species is investigated. The utilization of these resources could contribute to the FNS of the households in multiple ways.

Native potentially edible plant species play an important role as providers of alternative foods during cyclic or sudden food shortage periods (Humphry 1993; Vinceti et al. 2008; Arnold 2011; Vinceti et al. 2013). In most countries in Africa, where rural livelihoods are mostly dependent on the environment and natural resources, the valorization of the untapped potential of wild or poorly used native food species offers a feasible way to foster food security and poverty reduction. These species provide a variety of foodstuff such as fruit, seeds, tubers, flowers, sap, etc., which can be used not only directly for the enhancement of food and nutrition security of rural households, but also for generating new marketable products to improve the overall wellbeing of the households.

As many of these are species with an overlap of the harvesting calendar with the seasonal food shortage period, they can be effectively used to fill the food supply gap. Balemie and Kebebew (2006) reported that in the Derashe and Kucha districts of southern Ethiopia, about 18 species that are not regularly used as food are consumed during food shortages. Feyssa et al. (2011) identified 37 wild edible plants in Showa district, east Ethiopia, which can be harvested in all months, thus providing the community with continuous access to food and non-food products across the year. As the most of these areas have limited food storage infrastructure, these species could be of paramount importance in enhancing the FNS of the local smallholding farming households.

Yayu is endowed with a diversity of potentially edible plant species, as a large share of its vegetation cover remains untouched (Gole et al. 2009). These untapped resources have a great potential for improving the livelihoods of the communities (Senbeta et al. 2013). In the three AFP, 80 edible species were identified, and 25 of them were not actively used as a food. Similarly, Senbeta et al. (2013) reported 23 edible plants in the whole area of Yayu (Chapter 4).

Previous findings state that the smallholding farming households of Yayu suffer from seasonal food insecurity and eventually hidden hunger (Chapter 5). A multifaceted approach is necessary to achieve overall food security in the area, which should include improvements in the utilization of potentially edible species. This task requires a number of activities, from determining the nutritional and anti-nutritional factors to the cultivation and promotion of these species. The specific objectives of this part of the study were therefore:

- To quantify the macro- and micronutrient content of selected edible plant species of local AFP in Yayu.
- To quantify the anti-nutritional factors of potentially edible plants of local AFP in Yayu.

## 7.2 Methods

### 7.2.1 Species selection

Data was collected in 6 *kebele* in the Yayu Forest Coffee Biosphere Reserve (section 3.1). The selection of potentially edible species was conducted in two stages. First, the list of potentially edible species was presented to the 300 smallholding farming households. Then a transect walk across the AFP and the surrounding area together with local experts was performed to complement and refine the number of species.  A total of 12 species was finally selected based on their availability during the shortage season (Table 7.1.) Plant species identification was done using the local names and which were cross-checked by a local taxonomist using the specific literature (Mooney 1963; Kelecha 1987; Mesfin and Hedberg, 1995; Bekele, 1997; Bekele, 2007; and Teketay et al 2010).

In addition, a voucher of each specimen was prepared for the ambiguous and unidentified species and sent to the National Herbarium of Addis Ababa University, Ethiopia, for further identification. The edible parts of each sample were harvested from a healthy individual, and transported in an ice box to Jimma University for laboratory analysis.

Table 7-1. Potentially edible shortage season species of Yayu selected for nutritional analysis

| **Latin name** | **Common name** | **Main edible part** | **Food category** | **Mode consumption** | **Growth habit** | **Growing niche** |
|---|---|---|---|---|---|---|
| *Carissa spinarum* | Bush plum | Fruit | Fruit | Raw | Shrub | Forest/ AFP |
| *Ficus sycomorus* | Sycamore fig | Fruit | Fruit | Raw | Tree | Forest/ AFP |
| *Rubus apetalus* | Raspberry | Fruit | Fruit | Raw | Shrub | Forest/ AFP |
| *Syzygium guineense* | Water berry | Fruit | Fruit | Raw | Tree | Forest/ AFP |
| *Amaranthus graecizans* | Short-tepalled pigweed | Leaves | Vegetable | Cooked | Herb | Forest/wasteland land |
| *Dioscorea alata* | Purple yam | Tubers | Vegetable | Cooked | Herb | AFP |
| *Dioscorea cayensis* | Guinea yam | Tubers | Vegetable | Cooked | Herb | AFP |
| *Dioscorea prehensilis* | Yam | Tubers | Vegetable | Cooked | Herb | AFP |
| *Portulaca oleraceae* | Hogweed | Leaves/stem | Vegetable | Cooked | Herb | AFP |
| *Solanum nigrum* | Black nightshade | Leaves | Vegetable | Cooked | Herb | AFP |
| *Hypolepis sparsisora* | False bracken | Leaves | Vegetable | Cooked | Fern | Forest/wasteland land |
| *Tristemma mauritianum* | Tristemma | Fruit | Fruit | Raw | Shrub | AFP |

*AFP: Agroforestry plots*

### 7.2.2 Nutritional analysis

#### Proximate analysis

Proximate food composition analysis involved moisture, crude protein, crude fat, dietary fiber, ash, carbohydrates, and energy in accordance with the Association of Official Analytical Chemists (AOAC 2003).

Moisture and ash content was determined gravimetrically, and the percentage loss in weight was expressed as a percentage of moisture content. Crude fiber content was determined by a weight difference after acid-base digestion and burning the organic residue of the digestion. Crude fat was determined by exhaustive solvent extraction (petroleum ether b.pt 40-60°C) using a Soxhlet device. The difference in weight is expressed as a percentage (g/g) of crude fat content. Crude protein content was determined using the Kjeldahl method (Kjeldahl 1883), which involves a digestion of a given weight sample using $H_2SO_4$ and catalyst to convert into $(NH_4)_2SO_4$, decomposed with NaOH to liberate $NH_3$, distilled using 5% $BH_3O_3$, and then titrated using $C_{16}H_{18}ClN_3S$ red and blue. The value of nitrogen (N) obtained was multiplied by 6.25 to estimate the percentage of crude protein. The carbohydrate content was determined indirectly by deducting the estimated value of the above proximate factors from the total dry matter. Finally, the energy content was estimated by summing the multiplied values of crude protein, crude fat and carbohydrate (without crude fiber) by their AT WATER factor (4, 9, 4) as recommended by (AOAC 2003).

#### Mineral analysis

Acid-digested samples were used for elemental analysis. Iron (Fe), Magnesium (Mg), Zinc (Zn), Sodium (Na), Potassium (K), and Calcium (Ca) were determined using an atomic absorption spectrophotometer and flame photometer after digesting the samples using $HNO_3$ (AOAC 2003). Phosphor content was determined by the ammonium molybdate colorimetry method using a spectrophotometer following the standard procedure of the Association of Official Analytical Chemists (AOAC 2003).

#### Vitamin analysis

Vitamin A and vitamin C were selected for determination based on the available time and resources. The pro-vitamin A (beta-carotene) content was determined to apply the method by Sadler et al. (1990) and AOAC (1975) using a hexane-acetone-ethanol extraction solvent and analyzed by spectrophotometry. Vitamin C was determined using titration with iodine in accordance with the protocol followed by Sowa and Kondo (2003) and AOAC (1975). Finally, the amount of vitamin C was determined from the volume of titrate required for a standard solution.

**Anti-nutritional factor analysis**

Phytate, tannin and oxalate content determination were performed as anti-nutritional factor analyses. Phytate was determined using the Vaintraub and Lapteva (1988) method with a double beam UV-Vis spectrophotometer (Series UV/Vis spectrophotometer PG. instrument Ltd., T80, China). The colorimetric assay of phytate was formed and then centrifuged at 3000 rpm for 30 minutes to obtain a clear supernatant. Then its absorbance was measured at 500 nm using UV-Vis spectrophotometer by comparing against a series of standard solution of phytic acid. Finally, the concentration of phytates was calculated using the phytic acid standard curve and expressed as phytic acids in µg/100 g and then converted to mg/100g.

For the analysis of the tannin content of selected food samples, the protocol of Maxson and Rooney (1972) was employed using a UV-Vis spectrophotometer and a stock solution used as the standard solution (40 mg D-catechin in 100 mL 1% HCl in methanol). The final tannin content was quantified as mg of D-catechin per gram of sample.

Finally, the oxalate content was determined using the method of Ukpabi and Ejidoh (1989), which involves acid digestion, oxalate precipitation and permanganate titration.

All mineral, vitamin and anti-nutritional factor analyses were conducted in the plant nutrition laboratory of the Institut für Nutzpflanzenwissenschaften und Ressourcenschutz (INRES), University of Bonn.

## 7.3 Results

### 7.3.1 Proximate analysis

The moisture content of 12 potentially edible plants species of Yayu ranged between 42.1 g and 63.2 g per 100 g fresh edible portion (EP) of *Portulaca oleracea* and *Rubus apetalus*, respectively (Table 7-2). The ash content varied from 1.8 g (*Rubus apetalus*) to 18.8 g (*Amaranthus graecizans*) per 100 g dry EP. The highest amount crude fiber content was scored by the fruit of *Syzygium guineense* (6.4 g/100 g dry EP), while the lowest was in the tuber of *Dioscorea alata* (2.4 g/100 g dry EP). Crude fat content was highest in *Carissa spinarum* (15.2 g/100 g dry EP) was followed by *Syzygium guineense* (5.8 g/100 g dry EP) and *Ficus sycomorus* (3.0 g/100 g dry EP). The remaining species had relatively lower fat content. The highest crude protein content was in *Solanum nigrum* (19.26 g/100 g dry EP) followed by *Hypolepis sparsisora* (18.43g/100 g dry EP) and *Amaranthus graecizans* (17.95 g/100 g dry EP). Energy value varied strongly from 97.20 to 252.30 kcal/100 g dry EP. *Carissa spanarum* and *Syzygium guineense* were found to be richest in energy content. Variations in all proximate factors across the considered species were statistically significant ($p \leq 0.05$).

Table 7-2. Proximate factors content per 100 g edible portion of 12 potentially edible shortage season plant species of Yayu

| **Species** | **Moisture (g)** | **Ash (g)** | **Crude fiber (g)** | **Crude fat (g)** | **Crude protein (g)** | **Energy (kcal)** |
|---|---|---|---|---|---|---|
| *Amaranthus graecizans* | 46.4±1.4$^{EF}$ | 18.8±1.9$^{A}$ | 5.6±0.1$^{BC}$ | 0.6±0.5$^{F}$ | 18.0±1.0$^{A}$ | 142.0±0.5$^{C}$ |
| *Carissa spinarum* | 46.2±4.1$^{EF}$ | 9.8±0.8$^{D}$ | 3.1±0.3$^{DE}$ | 15.2±0.6$^{A}$ | 4.1±0.3$^{G}$ | 252.3±16.5$^{A}$ |
| *Dioscorea alata* | 51.3±0.9$^{D}$ | 5.5±0.7$^{E}$ | 2.4±0.6$^{E}$ | 0.6±0.6$^{F}$ | 8.46±0.9$^{CD}$ | 175.8±3.7$^{B}$ |
| *Dioscorea cayenensis* | 51.0±3.8$^{DE}$ | 4.3±0.6$^{E}$ | 3.8±0. 5$^{D}$ | 0.8 ±0.5$^{EF}$ | 7.6±1.2$^{D}$ | 183.0±14.6$^{B}$ |
| *Dioscorea prehensils* | 58.0±4.0$^{BC}$ | 4.5±0.7$^{E}$ | 3.5±0.3$^{D}$ | 0.7±0.6$^{F}$ | 7.3±1.5$^{DE}$ | 153.0±16.3$^{C}$ |
| *Ficus sycomorus* | 56.2±3.4$^{C}$ | 10.7±0.0$^{D}$ | 6.1±0.1$^{AB}$ | 3.0±0.8$^{C}$ | 6.0±0.2$^{EF}$ | 147.9±17.5$^{C}$ |
| *Hypolepis sparsisora* | 48.4±0.8$^{DE}$ | 17.6±3.1$^{AB}$ | 6.1±1.3$^{AB}$ | 1.4±0.7D$^{EF}$ | 18.4±0.9$^{A}$ | 143.0±5.9$^{C}$ |
| *Portulaca oleracea* | 62.5±0.4$^{AB}$ | 16.8±1.1$^{B}$ | 6.0±0.8$^{AB}$ | 2.8±0.2$^{C}$ | 15.6±0.7$^{B}$ | 97.2±1.5$^{D}$ |
| *Rubus apetalus* | 63.2±0.3$^{A}$ | 1.8 ±0.0$^{F}$ | 5.2±0.1$^{BC}$ | 2.2±1.0$^{CD}$ | 7.3±0.6$^{DE}$ | 151.2±3.9$^{C}$ |
| *Solanum nigrum* | 60.5±3.1$^{ABC}$ | 13.9±0.4$^{C}$ | 5.1±0.5$^{C}$ | 0.7±0.1$^{F}$ | 19.3±0.3$^{A}$ | 106.1±11.6$^{D}$ |
| *Syzygium guineense* | 42.1±2.4$^{F}$ | 4.0±0.2$^{E}$ | 6.8±0.0$^{A}$ | 5.8±1.5$^{B}$ | 9.8±0.7$^{C}$ | 244.5±16.5$^{A}$ |
| *Tristemma mauritianum* | 43.3±4.5$^{F}$ | 10.2±0.0$^{D}$ | 5.7±0.3$^{BC}$ | 1.9±0.3$^{CDE}$ | 4.7±0.9$^{FG}$ | 196.0±19.5$^{B}$ |
| CV (%) | 5.5 | 11.82 | 11.1 | 23.97 | 7.98 | 7.6 |

*Values expressed are means and SD of three replications.*
*In each column the mean values with different superscripts are significantly different ($p<0.05$).*
*All values were estimated dry except the moister content.*

### 7.3.2 Mineral analysis

Among the analyzed species, the highest Ca, Mg, Fe, and Ka contents were observed in *Amaranthus graecizans*, with 2065.0 mg, 1126.8 mg, 91.3 mg and 824.0 mg per 100 g dry EP, respectively (Table 7-3). The fruit-bearing plants *Rubus apetalus* and *Ficus sycomorus* had highest the Zn content with 6.5 and 5.0 mg/ 100 g dry EP, respectively. The tubers of *Dioscorea alata* (144.7 mg/100 g dry EP) and leaves of *Solanum nigrum* (93.8 mg/100 g dry EP) were the best potential suppliers of P. The maximum content of sodium per 100 g dry EP was observed in *Hypolepis sparsisora* (70.3 mg), while the minimum was in the fruits of *Carissa spinarum* (5.9 mg). Similarly, variations in mineral content among the 12 edible plants were statistically significant ($p \leq 0.05$).

Table 7-3. Mineral content in mg/100 g edible portion of 12 potentially edible shortage season plant species of Yayu.

| Species | Calcium | Magnesium | Iron | Zinc | Potassium | Sodium | Phosphorus |
|---|---|---|---|---|---|---|---|
| *Amaranthus graecizans* | 2065.0±195.0$^{A}$ | 1126.8±4.2$^{A}$ | 91.3±0.8$^{A}$ | 3.8±0.1$^{D}$ | 824.0±17.4$^{A}$ | 55.4±5.5$^{B}$ | 29.7±0.2$^{E}$ |
| *Carissa spinarum* | 130.0±10.0$^{F}$ | 77.5±0.0$^{I}$ | 4.0± 0.5$^{F}$ | 1.3±0.1$^{I}$ | 219.8±1.2$^{F}$ | 5.9±2.8$^{F}$ | 7.3±0.2$^{I}$ |
| *Dioscorea alata* | 75.0±5.0$^{F}$ | 68.7±1.8$^{I}$ | 12.8±0.0$^{E}$ | 2.2±0.1$^{G}$ | 293.7±2.5$^{E}$ | 28.8±3.7$^{D}$ | 144.7±0.8$^{A}$ |
| *Dioscorea cayenensis* | 1225.0±25.0$^{B}$ | 387.3±11.7$^{D}$ | 46.8±0.8$^{B}$ | 3.8±0.0$^{D}$ | 864.1±15.2$^{A}$ | 12.1±4.5$^{E}$ | 30.4±0.5$^{E}$ |
| *Dioscorea prehensils* | 80.0±10.0$^{F}$ | 116.2±8.2$^{H}$ | 12.8±2.3$^{E}$ | 2.3±0.0$^{G}$ | 287.3±9.0$^{E}$ | 12.3±0.3$^{E}$ | 12.5±0.2$^{H}$ |
| *Ficus sycomorus* | 321.2±2.9$^{E}$ | 303.5±4.7$^{F}$ | 14.7±0.7$^{DE}$ | 5.0±0.2$^{B}$ | 190.1±3.9$^{G}$ | 6.1±0.1$^{F}$ | 68.4±1.8$^{D}$ |
| *Hypolepis sparsisora* | 760.0±10.0$^{F}$ | 586.9±35.2$^{F}$ | 28.3±0.4$^{D}$ | 3.2±0.0$^{F}$ | 599.5±5.5$^{B}$ | 70.3±2.9$^{A}$ | 29.4±0.1$^{G}$ |
| *Portulaca oleracea* | 785.0±145.0$^{C}$ | 727.7±47.0$^{B}$ | 44.5±8.3$^{B}$ | 4.3±0.1$^{C}$ | 621.6±28.6$^{C}$ | 40.9±2.6$^{C}$ | 27.8±1.9$^{F}$ |
| *Rubus apetalus* | 150.0 ±20.0$^{C}$ | 246.5±0.0$^{C}$ | 18.5±1.1$^{C}$ | 6.5±0.1$^{A}$ | 831.2±0.3$^{D}$ | 11.7±2.8$^{E}$ | 16.4±0.4E$^{F}$ |
| *Solanum nigrum* | 585.0 ±5.0$^{D}$ | 172.5±3.5$^{G}$ | 24.1±3.0$^{C}$ | 1.6±0.1$^{H}$ | 176.8±6.0$^{G}$ | 13.0±4.8$^{E}$ | 93.8±1.6$^{B}$ |
| *Syzygium guineense* | 65.0±5.0$^{F}$ | 71.0±0.6$^{I}$ | 24.9±3.0$^{C}$ | 1.4±0.3$^{I}$ | 220.8±3.2$^{F}$ | 15.6±2.2$^{E}$ | 8.7±0.0$^{I}$ |
| *Tristemma mauritianum* | 275.0±25.0$^{E}$ | 138.5±0.0$^{GH}$ | 24.9±2.3$^{C}$ | 3.6±0.0$^{E}$ | 189.4±0.8$^{G}$ | 14.4±3.3$^{E}$ | 81.7±0.8$^{C}$ |
| CV (%) | 13.1 | 6.0 | 10.0 | 3.3 | 2.6 | 14.0 | 2.1 |

*Values are means and SD of three replications;*

*Mean values with different superscript letters are significantly different (p<0.05);*

### 7.3.3 Vitamin analysis

The β-carotene content of 12 edible plants as a source for vitamin A ranged between 0.1 mg and 0.2 mg per 100 g dry EP, the highest value was in *Rubus apetalus* (1.9 mg) (Table 7-4). *Syzygium guineense* was the richest in vitamin C (330.7 mg) followed by *Rubus apetalus* (294.19 mg). Variations among the two vitamins were statistically significant ($p \leq 0.05$).

Table 7-4. Vitamin A and C content in mg/100 g edible portion of 12 potentially edible shortage season plant species of Yayu.

| Species | β- carotene/vitamin A | Vitamin C |
|---|---|---|
| *Amaranthus graecizans* | $0.9 \pm 0.1^{B}$ | $180.7 \pm 19.7^{CD}$ |
| *Carissa spinarum* | $0.1 \pm 0.0^{F}$ | $256.6 \pm 9.7^{B}$ |
| *Dioscorea alata* | $0.5 \pm 0.1^{D}$ | $131.1 \pm 25.6^{E}$ |
| *Dioscorea cayenensis* | $0.2 \pm 0.0^{F}$ | $259.3 \pm 47.5^{B}$ |
| *Dioscorea prehensils* | $0.1 \pm 0.0^{F}$ | $296.2 \pm 33.6^{AB}$ |
| *Ficus sycomorus* | $0.2 \pm 0.0^{F}$ | $179.6 \pm 37.6^{CD}$ |
| *Hypolepis sparsisora* | $0.2 \pm 0.0^{F}$ | $198.0 \pm 12.8^{C}$ |
| *Portulaca oleracea* | $0.4 \pm 0.0^{E}$ | $191.0 \pm 15.8^{C}$ |
| *Rubus apetalus* | $1.9 \pm 0.2^{A}$ | $294.2 \pm 41.9^{AB}$ |
| *Solanum nigrum* | $0.8 \pm 0.6^{C}$ | $126.9 \pm 13.4^{E}$ |
| *Syzygium guineense* | $0.1 \pm 0.3^{F}$ | $330.7 \pm 27.8^{A}$ |
| *Tristemma mauritianum* | $0.2 \pm 0.0^{F}$ | $136.6 \pm 12.8^{DE}$ |
| CV (%) | 16.2 | 12.9 |

*Values are means and SD of three replications.*
*Mean values with different superscripts are significantly different ($p<0.05$);*

### 7.3.4 Anti-nutritional factors analyses

The phytic acid content of the 12 sampled species varied significantly ($p \leq 0.05$) with the maximum value of 0.6 mg/100 g dry EP in *Carissa spinarum* (Table 7-5.). In 5 species, no tannins were detected. However, in the other species, high values were observed, reaching up to 3974 mg/100 g in *Syzygium guineense*. The total oxalate content was observed to fluctuate from 0.8 mg/100 g (*Carissa spinarum*) to 4.2 mg/100 g (*Amaranthus graecizans*).

Table 7-5 Anti-nutritional factors content in mg/100 g dry edible portion of 12 potentially edible shortage season plant species of Yayu.

| Species | Phytate | Tannin | Total oxalate |
|---|---|---|---|
| *Amaranthus graecizans* | 0.4±0.0$^{D}$ | 405.4±75.0$^{E}$ | 4.22±1.4$^{A}$ |
| *Carissa spinarum* | 0.6±0.0$^{A}$ | 1313.0±89.0$^{C}$ | 0.8± 0.3$^{E}$ |
| *Dioscorea alata* | 0.1±0.0$^{H}$ | ND | 2.5±0.4$^{BC}$ |
| *Dioscorea cayenensis* | 0.1±0.0$^{H}$ | 837.4±13.0$^{D}$ | 2.8±0.0$^{B}$ |
| *Dioscorea prehensils* | 0.0±0.1$^{I}$ | ND | 2.8±0.3$^{B}$ |
| *Ficus sycomorus* | 0.4±0.1$^{E}$ | 1963.0± 241.0$^{B}$ | 1.8±0.4$^{CD}$ |
| *Hypolepis sparsisora* | 0.2±0.0$^{F}$ | ND | 1.8±0.4$^{CD}$ |
| *Portulaca oleracea* | 0.2±0.0$^{F}$ | ND | 2.32± 0.2B$^{CD}$ |
| *Rubus apetalus* | 0.2±0.0$^{F}$ | ND | 2.1±0.4$^{BCD}$ |
| *Solanum nigrum* | 0.5±0.0$^{B}$ | 756.0±139.0$^{D}$ | 1.4±0.3$^{DE}$ |
| *Syzygium guineense* | 0.5±0.0$^{C}$ | 3973.6±422.0$^{A}$ | 1.7±0.8$^{CDE}$ |
| *Tristemma mauritianum* | 0.2±0.0$^{F}$ | 315.9±9.0$^{EF}$ | 2.5±0.3$^{BC}$ |
| CV (%) | 7.7 | 21.8 | 24.6 |

*ND- not determined because tannin content was negligible.*
*Values expressed are means and SD of three replications.*
*In each column the mean values with different superscripts are significantly different ($p<0.05$);*

## 7.4 Discussion

The three species with the highest values of each nutritional and anti-nutritional parameter were compared with the three most common food crops (section 4 and 5) in the shortage and surplus seasons of Yayu. For protein and vitamin-C content, a further three food crops rich in these nutrients are considered.

The comparison of energy and crude protein content of the three species with the highest amount of each of the specific nutrients (top three) against the common food crops of surplus and shortage season is presented in Figure 7-1.

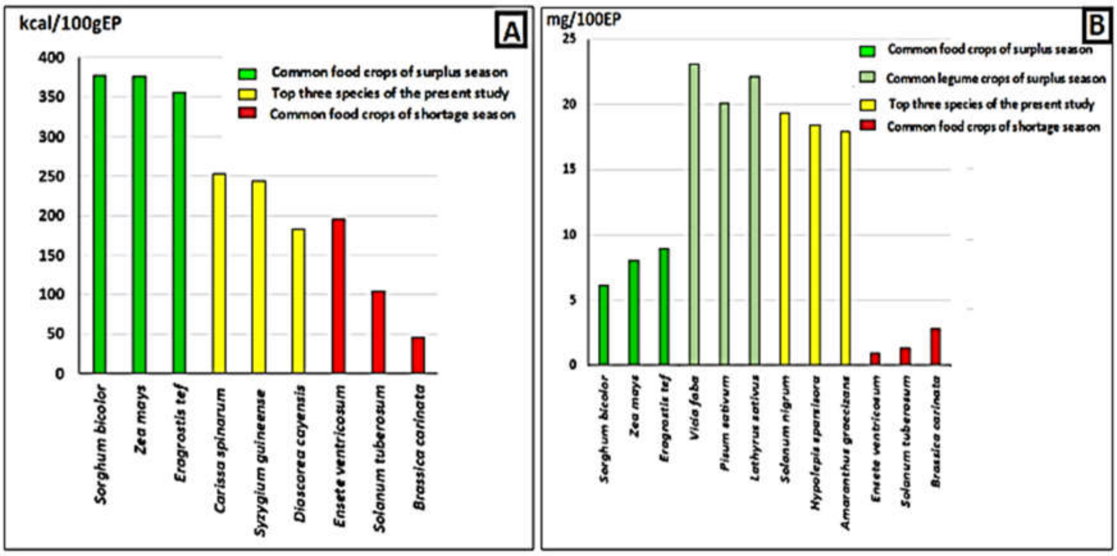
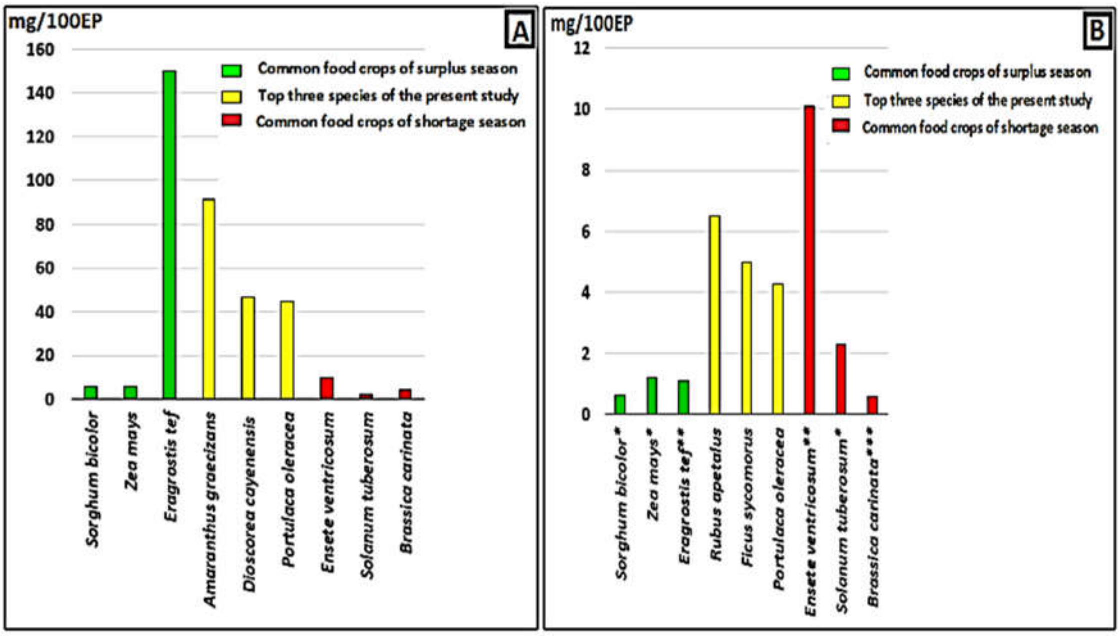


Figure 7-1 Comparison of the nutrient contents of the three most nutrient-rich potentially edible species against the commonly consumed species in the surplus and shortage season in Yayu. A: energy content, B: crude protein content

In comparison with the common surplus season cereal crops such as *Zea mays* (376 kcal/100 g dry EP), *Sorghum bicolor* (377.4 kcal/100 g dry EP) and *Eragrostis tef* (355.1 kcal/100 g dry EP), the energy content of the potentially edible shortage season species was low (Figure 7-1A). However, the energy value of the two most nutrient-rich species, namely *Carissa spinarum* (252.3 kcal/100 g dry EP) and *Syzygium guineense* (244.5 kcal/100 g dry EP) was higher than the common shortage season crops such as *Ensete ventricosum* (196.0kcal/100 g dry EP), *Solanum tuberosum* (103.7 kcal/100 g dry EP) and *Brassica carinata* (46.00 kcal/100 g dry EP). This indicates the great potential of the potentially edible plant species to improve the dietary energy supply in Yayu.

Protein content in the three species with the highest protein content was slightly lower than in the three most common sources of protein *Vicia faba*, *Pisum sativum* and *Lathyrus sativus* (Figure 7-1B). However, these species scored higher (> 15 g/100 g dry EP) than the surplus season food crops *Sorghum bicolor* (6.3 g/100 g dry EP), *Zea mays* (8.1 g/100 g dry EP) and *Eragrostis tef* (9.0 g/100 g dry EP), and the shortage season food *Ensete ventricosum* (0.9 g/100 g dry EP), *Solanum tuberosum* (1.3g /100 g dry EP) and *Brassica carinata* (2.8 g/100 g dry EP). This reveals the potential of the targeted species for enhancing the smallholding farming households' access to protein. However, the present study only focused on crude protein content, a detailed analysis on the amino acid composition of each species is still required.

The comparative analysis of each mineral of the top three species with common food crops of the surplus and shortage seasons (Figure 7-2) reveals that with respect to Fe, the former scored higher than all other species considered except *Eragrostis tef*. Similarly, the Zn content of the top three potentially edible species exceeded that of all other species considered except the popular shortage season food *Ensete ventricosum*. In both cases, the potential of the target species to enhance the mineral supply of the smallholding farming households was not limited only to the shortage season but also to the surplus season. However, further studies are required on storing techniques of such food as these species are available only during the shortage season.



**porridge; ** unfermented baked and ***boiled*

Figure 7-2. Comparison of mineral content of top three potentially edible species against the commonly consumed species in the surplus and shortage season in Yayu. A: Iron content, B: Zinc content

The food crops common in the surplus season do not contain a detectable amount of vitamin A or C (Figure 7-3). Despite being the most common vitamin-A source, *Capsicum annuum* scored lower β- carotene than *Rubus apetalus*. All the top three vitamin-rich potentially edible species had higher β-carotene contents than the commonly consumed shortage season foods except the dark green vegetable *Brassica carinata* (Figure 7-3A). The top three edible species were 300% richer in Vitamin C than the common vitamin-C rich species of the area (Figure 7-3B)

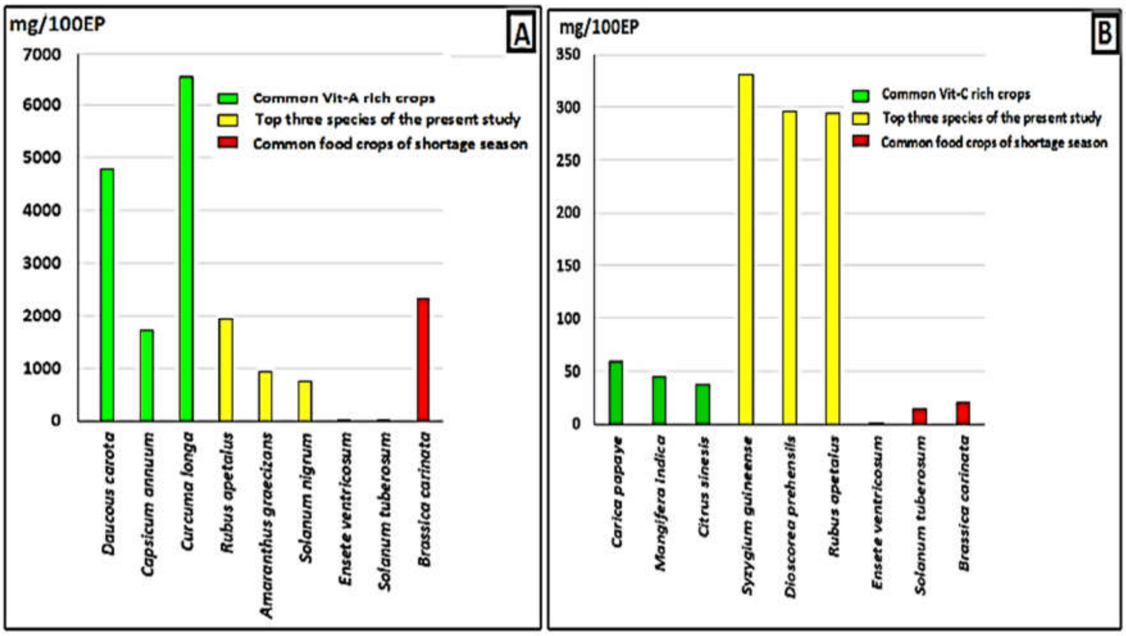


Figure 7-3. Comparison of vitamin contents of top three potentially edible species with the commonly consumed species in the surplus and shortage season in Yayu. A: Vitamin-A content; B: Vitamin-C content

The anti-nutritional contents of the top three species were compared with the respective lethal doses stated by Inuawa (2011) (Table 7-6). All values were considerably low except tannin. The tannin content of all species except 5 were considerably high. This indicates the need to conduct a study on the pre- and postharvest processing technologies to reduce this factor.

Table 7-6. Comparative summary of the top three species of Yayu for three anti-nutritional factors and their respective lethal dose (Inuawa 2011).

| Anti-nutritional factor | Lethal dose (mg/100 g EP) | Top three species | Content (mg/100 g EP) |
|---|---|---|---|
| Phytate | 5.0 | *Carissa spinarum* | 0.60 |
| | | *Solanum nigrum* | 0.54 |
| | | *Syzygium guineense* | 0.48 |
| Tannin | 3.0 | *Syzygium guineense* | 3973.6 |
| | | *Ficus sycomorus* | 1963.0 |
| | | *Carissa spinarum* | 1313.0 |
| Total oxalate | 200-500 | *Amaranthus graecizans* | 4.2 |
| | | *Dioscorea prehensilis* | 2.8 |
| | | *Dioscorea cayenensis* | 2.8 |

## 7.5 Conclusions

It is concluded that the potentially edible species with harvestable parts during the shortage season have a considerable potential to contribute to filling the seasonal food and nutrition insecurity and possible hidden hunger of the Yayu area. More specifically, *Carissa spinarum* and *Syzygium guineense* are fruit-bearing species with high potential to supply calorific requirements. Regarding the protein supply, *Solanum nigrum* and *Hypolepis sparsisora* are leafy vegetables of high protein content. However, a detailed analysis on the composition of amino acids is needed before utilizing them as protein sources.

Regarding micronutrient provision, *Amaranthus graecizans*, *Dioscorea cayenensis* and *Hypolepis sparsisora* were the food stuff richest in minerals such as Ca, Mg and, most importantly, Fe. *Rubus apetalus* and *Amaranthus graecizans* are fruit and leafy vegetables which exceed the other species in vitamin-A content. Regarding Fe supply, the species were not promising to boost the detected Fe shortage in the people. Furthermore, the low level of the anti-nutritional factors phytate and oxalate could facilitate the utilization of these resources, but a mechanism to lower the tannin content of species with high tannin contents is needed.

# 8 SYNTHESIS AND CONCLUSIONS

## 8.1 Synthesis

The overall influence of local AFP on the FNS of smallholding farming households in Yayu is confirmed (Chapter 6). A summary is provided below based on their contribution to the five pillars of FNS.

### 8.1.1 Contribution to the 'availability' pillar

The annual food supply is mainly supplied by the MTF plots. The cereal staples *Zea mays*, *Sorghum bicolor*, *Eleusine coracana,* and *Eragrostis tef,* the major source of dietary energy, are the species most commonly cultivated, as they are main ingredients of the popular dish Enjera/Bidena (Chapter 4). However, these may not cover the full food demand when farmers face the food shortage season (rainy season from July to September). This situation is made more difficult through low productivity, wild animal damage, lack of land, and large family size as the most prominent reasons (Etissa et al., 2016; key informant communication July, 2014).

Different coping mechanisms are implemented to fill this seasonal food supply gap, cultivating food in HG being the most common (Section 4). Perennial staple species, such as *Ensete ventricosum*, which is available throughout the year, and roots and tubers like *Colocasia antiquorum*, *Dioscorea alta,* and *Solanum tuberosum*, are among the preferred food species cultivated in the HG for the shortage season. Leaf vegetables like *Brassica oleracea* var. capitata, *B. carinata* and *B. oleracea* var. oleracea from MTF and HG ( Chapter 4) are also important contributors to the food availability pillar.

According to the local people, the food production scheme is highly challenged by crop damage caused by the wild animals in the forests. For the farmers living near the forest, the costs incurred from protecting the food crops is so high that they are sometimes discouraged to produce their own food but rather rely on market goods. The tree components such as *Erythrina abyssinica*, *Maesa lanceolata*, *Rubus apetalus*, *Vernonia auriculifer,* and *Justicia schimperiana*, which are regularly cultivated as hedgerows and live fences, play a significant role in protecting the food crops. In addition, these trees protect the plots from wind and soil erosion.

Tree components, particularly in MTF plots, also enhance the availability of food by optimizing the annual harvest of crops from the plots by fertilizing the soil and minimizing the costs for purchasing inorganic fertilizer. Although the present study did not cover a quantitative assessment of the benefit of leguminous trees species on the MTF plots, it can be assumed that they are maintained due to their multiple benefits, including the fertilization of the plots. *Albizia grandibracteata*, *Albizia gummifera*, *Albizia schimperiana*, *Erythrina abyssinica*, *Leucaena leucocephala*, *Sesbania sesban* and *Acacia abyssinica* are the N-fixing species most frequently managed on MTF plots in Yayu (Chapter 4).

Farming practices of Yayu's smallholding households are totally dependent on animal traction. Without this, almost all food produced in the MTF plots would not be functional. A further contribution of AFP in Yayu thus comes from the 'fodder' utilities generated by the three practices. Fodder species such as *Vernonia amygdalina*, *Sapium ellipticum*, *Dracaena fragrans*, *Sesbania sesban*, *Leucaena leucocephala*, and *Ficus sur* are the most common sources of feed to supplement the annual farming feedstock.

Based on the correlations between attributes of AFP and FNS ( Chapter 6), households who have do not have MTF and HG scored the highest HFIAS, i.e. are more food insecure in both seasons, indicating the potential role of both practices. In addition, the species richness in both practices was associated with the food security status of the households. These factors indirectly indicate the importance of the two practices for food availability.

### 8.1.2 Contribution to the 'access' pillar.

Among the major expenses of the households are those for spices and flavoring and coupled with agricultural inputs such as seeds and fertilizers (key informants communication July, 2014). Therefore, the importance of generating sufficient cash to cover these costs is critical for achieving FNS.

In Yayu, 81% of the rural households' annual income is from the three dominant AF practices, where the main share comes from MCS, accounting for 60% of the total income including off-farm activities (Chapter 4). Therefore, the main contribution of MCS to household FNS is the generation of cash to enhance the food acquisition capabilities and sustain livelihoods. Coffee is the major crop used to generate income from MCS and HG plots. According to the farmers, even households with small farms or even no farmland, and social groups marginal to the conventional market channels such as poor women and children benefit from coffee through the mechanism named *Kote*, which allows them to collect and trade coffee left over after the main harvest. Regardless of its actual importance, the high dependency on coffee may lead to vulnerability of the Yayu communities through national and international price fluctuations.

Following the food shortage season from July to September, there is a cash supply and income gap from September to December, when the households have consumed their food stocks and spent their savings on food from the market. Farmers sell their coffee harvest in bulk at lower prices, as they fear a reduction in coffee volume through storage losses and price declines (key informants communication July, 2014). In that setting, farmers try to increase their income through selling other merchantable agricultural products from HG and MTF (Chapter 4). For instance, *Catha edulis*, being harvested two to three times a year, ensures a continuous flow of cash. The same applies to exotic fruits (e.g. *Mangifera indica*, *Musa paradisiaca* and *Persea americana*), vegetables (e.g. *Solanum lycopersicum* and *Allium cepa*), timber tree species (e.g. *Eucalyptus grandis*), spices (e.g. *Zingiber officinale* and *Curcuma longa*), and other cash crops (e.g. *Saccharum officinarum* and *Rhamnus prinoides*), which are sold in local (less competitive) markets (Chapter 4).

Furthermore, the three AFP indirectly contribute to boosting the households' income via providing production media and feedstock for diary and honey production. Households who own only HG, mainly managed by females, were observed engaging in diary production to supply markets with byproducts like butter. The main source of feedstock for their cows is fodder and grass grown in HG. Furthermore, honey production is a side benefit from the tree components of all practices in a number of ways, such as hanging the hives, making and smoking the hives, and a sustainable provision of bee forage. These activities have a great potential for improving the income of the smallholders in Yayu, however they are not fully exploited mainly due to limitations in labor and technology.

The area is endowed with a considerable number of other species of active and passive marketability potential. For instance, Gole et al. (2009) and Senbeta et al (2013) reported that the semi-managed and natural coffee forest of Yayu possesses high-value market commodities such as the spice crops *Aframomum corrorima* and *Piper capense,* and the timber tree *Cordia africana*. The utilities of the latter species to benefit the FNS of the smallholding farming households have not yet been identified, indicating the necessity to facilitate its optimum utilization in the area. However, such tree species are currently facing overexploitation, demanding effective conservation and management (Gole et al. 2009) before any type of utilization such as fruit and seed collection is possible.

Cash generation is an important component of the FNS of Yayu in many ways. For instance, the main dish is regularly served together with a stew as a flavoring element. The most popular ingredient of the stew is grass pea (*Lathyrus sativus*), which is also an important source of protein (Chapter 5). This was not observed in the farm plots in Yayu, and is bought from the markets. Other inputs such as oil, spices and salt are also purchased from the markets. Thus, without sufficient cash, the diet of the smallholding farming households in Yayu will never be complete.

Finally, all farming practices demand a significant amount of cash to cover management, harvesting, preparation and transport costs. Henceforth, improving the households' income and diversifying its sources will be of paramount importance in enhancing not only the access pillar of FNS but also the overall sustainability of the farming in the area.

### 8.1.3 Contribution to the 'utilization' pillar

The main component of the utilization pillar is a balanced diet, which can be achieved by making available diversified foods rich in macro- and micronutrients. In this regard, protein and other essential micronutrients in Yayu are mostly supplied by HG. The HG plots produce relatively diversified foods such as fruits, vegetables, roots, tubers, nuts vegetables with dark green leaves, and sometimes legumes, whereas the MTF plots are dominated by cereals (Chapter 4). Focusing on the three important macro- and micronutrients protein, vitamin A, and iron, the contribution of local AFP is discussed below.

Concerning macronutrients, despite the consumption of animal protein in Yayu being very low, milk, eggs, and even meat are produced in HG (Chapter 5). However, pulses like *Lathyrus sativus*, *Vicia faba*, *Pisum sativum*, *Cicer arietinum*, *Phaseolus lunatus* and *Phaseolus vulgaris*, although mainly purchased from the markets, remain the primary sources of protein for most farming households (Chapter 5). The consumption of protein by WRA is limited during the shortage season but improves for the children because of the availability of milk as the abundant rainfall increases the quality of the pastures during this season.

All AFP contribute to the enhancement of protein consumption by providing fodder for livestock. *Vernonia amygdalina* and *Sesbania sesban* are widely cultivated in HG to supplement animal feedstocks. Furthermore, *Sesbania sesban*, *Leucaena leucocephala*, *Vernonia amygdalina* and *Ficus sur* are multipurpose tree species maintained in MTF for animal fodder (Chapter 4).

Concerning vitamin A, HG is the prime source of foods rich in this micronutrient through 'dark green leafy vegetables', vitamin-A-rich roots and tubers', and 'vitamin-A rich fruits and vegetables' like *Brassica carinata* and *Brassica oleracea* var. *oleracea*, *Carica papaya*, *Prunus persica*, Daucus carota, *Cucurbita pepo*, and *Capsicum frutescens* (Etissa et al., 2016; Chapter 4 and 5). As most 'dark green vegetables' and 'vitamin-A-rich roots and tubers' are considered shortage season foods, the consumption of vitamin A is considerably better in the shortage season than in the surplus. During the surplus season, the availability of starchy cereals determines diets richer in carbohydrates and poor in vitamin A. Introducing vitamin-A-rich maize varieties could be an alternative.

Minerals, Fe in particular, scarce in Yayu due to the limited consumption of animal protein (heme iron), can effectively be substituted by non-heme iron from *Eragrostis tef* cultivated in MTF and/or purchased from the markets (Chapter 4). This deficiency will remain chronic unless measures are implemented, mainly by enhancing the consumption of animal products. Alternatively, Yayu is endowed with potentially edible native species rich in Fe such as *Amaranthus graecizans*, *Dioscorea cayenensis* and *Portulaca oleracea* (Chapter 7), which can compensate the possible Fe deficiency in the area. In addition, the AFP comprise other species rich in active nutrients such as *Citrus spp*., *Mangifera indica*, *Musa paradisiaca*, *Persea americana*, *Solanum tuberosum*, *Solanum lycopersicum*, *Beta vulgaris* and *Allium cepa* (Chapter 4); and potentially edible species such as *Syzygium guineense*, *Phoenix reclinata*, *Cordia africana*, *Mimospis cummel*, *Rubus apetalus*, *Bridelia micrantha* and *Dovyalis abyssinica*, which are rich in other micronutrients like Zn, vitamin C and Ca (Chapter 4, 5, and 7).

When the edible plant species richness in each AFP (Chapter 4) is compared with the nutritional status of householders (cereal-dominated diets leading to hidden hunger; Chapter 5), it is clearly shown that these plant resources are not optimally utilized, at least at the time of this study. This might be due to the increased dependency on the sales of coffee beans and other cash crops for purchasing food. Henceforth, a mechanism should be devised to improve the utilization of underutilized edible plant species as a supplementary food to fill the detected gap (Chapter 7).

The observed association among the FNS indicators and different attributes of AFP especially during the shortage season (Chapter 6) confirms their association with independent factors such as socioeconomic attributes of the households. For instance, the wealth status of a household is associated with the richness of 'active food' species (Chapter 4) and FNS (Chapter 5). Similarly, the diversity food groups rich in micronutrients are associated with the ethnicity (Chapter 4), which ultimately could reflect on the FNS. Therefore, factors that affect the form and performance of the AFP affect the FNS status of the smallholding farming households.

Another aspect of utilization is making safe food, which mainly refers to proper handling and cooking. According to FAO (2008), cooking not only makes foods safe, it also allows optimal release of the energy and nutrients for effective utilization by the body. In this regard, almost the all smallholding farmers in Yayu obtained almost all cooking energy from their AFP plots (Chapter 4; key informants communication July, 2014). In MCS, fuelwood is harvested from the upper and understorey vegetation mainly from *Acacia abyssinica*, *Maytenus arbutifolia* and *Maesa lanceolata*. In addition, the dried branches of shade trees and coffee crops and the biomass from pruning and weeding in the MCS plots contribute to a continuous supply of fuel throughout the year (key informants communication July, 2014).

At the same time, the HG and MTF plots are used for fuel from the component species, i.e. *Croton macrostachyus*, *Ricinus communis*, *Vernonia auriculifer*, *Justicia schimperiana*, *Sapium ellipticum* and *Ritchiea albersii*, which are popular fuelwood species (Chapter 4). In general, the local AFP of Yayu ensure a sustainable supply of affordable fuel for the households so that they can access safe and healthy food throughout the year.

### 8.1.4 Contribution to the 'stability' pillar

This relates mainly to the diversity of attributes, which operate in two main ways, i.e. making AFP less prone to climatic and other environmental calamities, and enabling continuous harvesting of edible and marketable products throughout the year.

In Yayu, the presence of the woody components and species diversity within and between practices prevent crop failure and minimize yield fluctuations. HG host about 85 species, out of which more than 50% are perennial (Chapter 4). These create environmental conditions less susceptible to climatic extremes thus protecting annual food species. In MCS, almost all species are perennial and less prone to climatic fluctuations. In this AFP, *Albizia gummifera*, *Acacia abyssinica, Cordia africana*, *Albizia grandibracteata* and *Croton macrostachyus* are the most common shade tree species (Chapter 4). In the case of MTF, trees play a significant role in maintaining soil fertility and preventing erosion, and when planted as hedges prevent damage by animals, wind, and frost (key informants communication July, 2014). *Eucalyptus grandis*, *Vernonia amygdalina, Vernonia auriculifer* and *Catha edulis* are the most frequent trees performing these functions in MTF (Chapter 4).

Harvesting diversified products also fills the seasonal gap in cash and food supply due to the non-concurrent phenological stages of the species. For instance, the harvest of *Catha edulis* and fruits such as *Mangifera indica*, *Musa paradisiaca* and *Persea americana* enables the households to generate cash during non-coffee harvesting periods, which helps to cover household expenses. Similarly, the food crop *Ensete* *ventricosum* from HG available all year round is used whenever a food is depleted in a household (Chapter 4).

### 8.1.5 Contribution to the 'sovereignty' pillar

Of the three AFP of Yayu, the highest contributor to the sovereignty pillar is the HG. This is evidenced by the abundance of native species cultivated for household consumption and in less demand by the markets. For example, the cultivation of the indigenous shortage season food crops *Ensete ventricosum*, *Brassica carinata* and Brassica oleracea var. *oleracea*, *Colocasia antiquorum* and *Dioscorea alta* is limited to HG (Section 4). In addition, most HG are managed by the women (Chapter 4), who are responsible for the household's food, so they have relatively better rights with respect to types of crops cultivated in the HG (Patel 2012).

The MTF contribute to some extent toward food sovereignty by allowing the farmers to choose among the cereals and pulses those which are suitable for the site conditions and the availability of land and labor. In fact, those households near to markets for the type of cereals and pulses cultivated on their MTF are considerably influenced by the market demand. For instance, *Eragrostis tef* is cultivated mainly for sale at the market by outsourcing cheaper cereals such as *Sorghum bicolor* and *Zea mays* (key informants communication July, 2014).

As the area is dominated by cash crops, the demand for food from the markets is high, especially during the coffee harvesting period (December to March), so the local definition for food security is different during this season (key informants communication July, 2014), and is more related to income security. Income generated from MCS plots usually contributes to the income security of the smallholding farming households (Chapter 4), which ultimately contributes to the food sovereignty pillar by allowing the households to choose food from the market.

## 8.2 Conclusions

Based on the information obtained from the four specific studies in the overall study of FNS, it can be concluded that AFP have a considerable actual and potential role in maintaining and enhancing the FNS of smallholding farming households in Yayu. The major findings of the study are systematically presented in Figure 8-1.

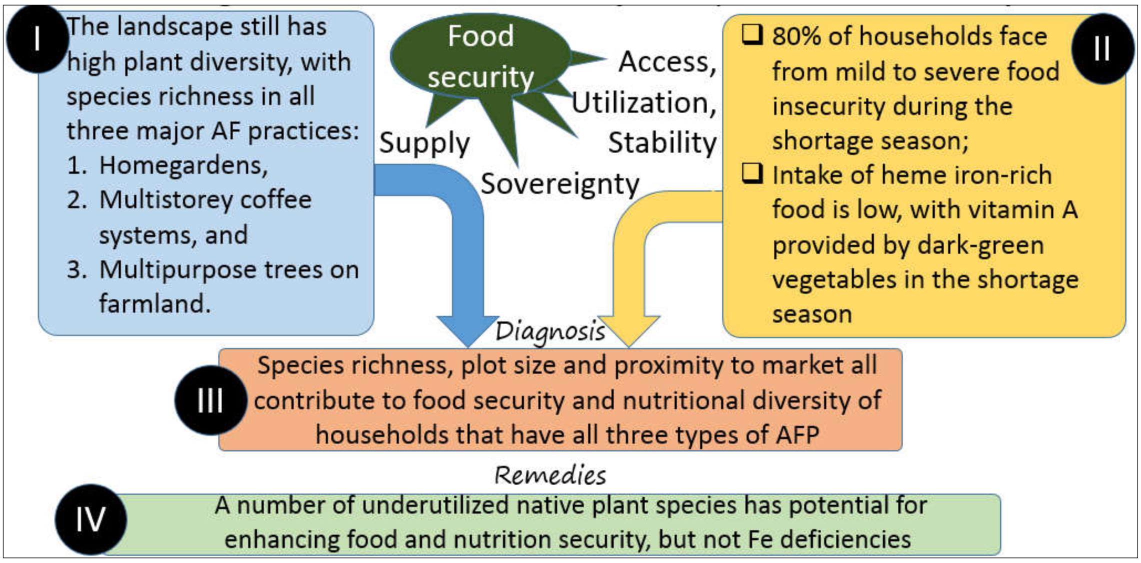


Figure 8-1 Main findings of the study on the potential of agroforestry practices for food and nutrition security

Three AFP are carried out by the smallholding farming households of Yayu, namely multistorey-coffee-system (MCS), multipurpose-trees-on-farmlands (MTF) and home garden (HG). Despite having specific purposes, management and species, these contribute substantially to the four pillars of FNS of households and communities. In a complementary manner, all contribute to satisfying the various demands of the farming households. The coffee-dominated plots mainly generate cash through the sales of coffee beans, non-timber forest products, and fuelwood. Farmlands surrounded by trees produce the main annual food supply, which is complemented by HG, which sometimes also may produce supplementary income. Therefore, a contribution to the communities' well-being may result from the benefits of each of these practices, but it would be potentiated by the synergetic performance of all three.

Focusing on the benefits of peoples' food and nutrition, the roles of the AFP, despite showing some overlapping, are differential: a) the MTF displays more benefits in the availability pillar, b) the MCS shows a major potential toward the access pillar, and c) HG are crucial for the utilization and sovereignty pillar. In all three cases, the presence of woody components and the diversity of species greatly favor the stability pillar. In addition, the area is endowed with an untapped potential of edible and marketable plant species, which can further enhance the four pillars of FNS.

A large share of the smallholding households in Yayu is relatively food and nutrition secure, signifying the importance of the AFP identified. Nonetheless, there was a significant proportion of the households facing seasonal food insecurity, which was not identified in official reports. Furthermore, it is known that the starch-dominated diet in the area exposes a large number of people to possible hidden hunger. All in all, the majority of the Yayu inhabitants achieve all pillars of food security except the utilization pillar with its seasonal fluctuation. However, different coping strategies are implemented by the communities to overcome this situation.

An association between different attributes of the AFP and the FNS is confirmed. This suggests that an intervention to improve the performance of the AFP will certainly enhance the FNS status of the households. However, as the evaluation did not consider the causalities of the respective attributes, the generalizations might be misleading. In general, attributes can be influenced by multiple factors, such as a household's socioeconomic situation, its location (proximity to market and forest), or the assumed purpose of the production, and the respective management of the practice.

It can be concluded that the edible species available during the shortage season have the potential to fill the seasonal food shortage in the area and even mitigate the latent hidden hunger. However, a detailed study on how to manage, harvest and consume the foods obtained from the species in question is required.

In general, the results of this study reveal the potential role of and relationship between the AFP and FNS of the smallholding farming households mainly on the basis of proxy tools. A more detailed investigation is required to gain a sound knowledge about the two parameters. Among the proposed evaluations, a clinical-based nutrition assessment of individuals is the most important. Furthermore, downscaling and fine-tuning the analyses to the individual level to optimize the role of AFP on the FNS of the smallholders. The contribution of indigenous, native and/or underutilized species growing in all AFP should also be taken into account. This all demands detailed, empirical, and interdisciplinary investigations involving the interface of the social-ecological systems with the FNS of the household members.

On the other hand, ongoing changes such as the thriving infrastructural development in the area may pose a risk to the stability and sustainability of the AFP. Therefore, subsequent studies may need to add the resilience/adaptive aspect.

Therefore, the following recommendations are made based on the findings of this study:

- Further studies on recognizing and conserving the traditional knowledge regarding the management of all types of AFP of Yayu is required so that it can be applied to other regions of the country.
- A further assessment of potentially edible species from the intact forest and farming systems of Yayu for all months of the year is crucial to address the detected seasonal food insecurity and hidden hunger.
- The study should also be replicated to other areas with different agro-ecological and/or socioeconomic setups so as to strengthen the knowledge regarding the contribution of AFP to FNS of smallholders.
- Technical studies and innovations with respect to domestication, management, harvesting, post-harvesting, storing and processing of food harvested from potentially edible species are required to facilitate the sustainable and effective utilization of the untapped plant resources of Yayu.

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# 10 APPENDIX

Appendix 1. Species identified in Yayu (sorted by main purpose and plant family)

| Scientific Name | Common Name | Local Name | Family | Growth Form | Main Purpose | Marketability | Niche |
|---|---|---|---|---|---|---|---|
| *Beta vulgaris* | Beet root | Qey sir | Amaranthaceae | Herb | Fd | A | HG |
| *Allium fistulosum* | Onion | Qey shinkurt | Amaryllidaceae | Herb | Fd | A | HG |
| *Allium sativum* | Garlic | Nech Shinkurt | Amaryllidaceae | Herb | Fd | A | HG |
| *Mangifera indica* | Mango | Mango | Anacardiaceae | Tree | Fd | A | HG |
| *Annona cherimola* | Cherimoya | Gishta | Annonaceae | Shrub | Fd | A | HG |
| *Daucus carota subsp. Sativus* | Carrot | Carrot | Apiaceae | Herb | Fd | A | HG |
| *Colocasia antiquorum* | Taro | Godere | Araceae | Herb | Fd | P | HG |
| *Lactuca sativa* | Lettuce | Selata | Asteraceae | Herb | Fd | A | HG |
| *Brassica carinata* | Abyssinian mustard | Abrango | Brassicaceae | Herb | Fd | A | HG |
| *Brassica oleracea* | Kale | Gomen | Brassicaceae | Herb | Fd | A | HG |
| *Brassica oleracea var.capitat* | White cabbage | Tikil Gomen | Brassicaceae | Herb | Fd | A | HG |
| *Ananas comosus* | Pineapple | Ananas | Bromeliaceae | Herb | Fd | A | HG |
| *Ipomoea batatas* | Sugar beet | Sukar dinich | Convolvulaceae | Herb | Fd | A | HG |
| *Coccinia abyssinica* | Anchote | Anchote | Cucurbitaceae | Herb | Fd | A | HG |
| *Cucurbita pepo* | Pumpkin | Duba | Cucurbitaceae | Herb | Fd | A | HG |
| *Manihot esculenta* | Cassava | Muka furno | Euphorbiaceae | Shrub | Fd | P | HG |

| **Scientific Name** | **Common Name** | **Local Name** | **Family** | **Growth Form** | **Main Purpose** | **Marketability** | **Niche** |
|---|---|---|---|---|---|---|---|
| *Cicer arietinum* | Chick pea | Shimbra | Fabaceae | Herb | Fd | A | HG, MTF |
| *Phaseolus lunatus* | Lima bean | Adengure | Fabaceae | Herb | Fd | A | HG |
| *Phaseolus vulgaris* | Haricot bean | Boloqe | Fabaceae | Herb | Fd | A | HG, MTF |
| *Pisum sativum* | Garden pea | Ater | Fabaceae | Herb | Fd | A | HG, MTF |
| *Vicia faba* | Faba bean | Baqela | Fabaceae | Herb | Fd | A | HG, MTF |
| *Persea americana* | Avocado | Avocado | Lauraceae | Tree | Fd | A | HG |
| *Linum usitatissimum* | Flax | Telba | Linaceae | Herb | Fd | A | HG |
| *Artocarpus heterophyllus* | Jackfruit | Jackfruit | Moraceae | Tree | Fd | A | HG |
| *Ensete ventricosum* | False banana | Enset | Musaceae | Herb | Fd | P | HG |
| *Musa paradisiaca* | Banana | Muzi | Musaceae | Herb | Fd | A | HG |
| *Psidium guajava* | Guava | Zeytuna | Myrtaceae | Shrub | Fd | A | HG |
| *Eleusine coracana* | Finger millet | Dagusa | Poaceae | Herb | Fd | A | TF |
| *Eragrostis tef* | Love grass | Teff | Poaceae | Herb | Fd | A | TF |
| *Hordeum vulgare* | Barley | Gebs | Poaceae | Herb | Fd | A | HG, MTF |
| *Sorghum bicolor* | Sorghum | Mashila | Poaceae | Herb | Fd | A | HG, MTF |
| *Triticum sativum* | Wheat | Sinde | Poaceae | Herb | Fd | A | TF |
| *Zea mays* | Maize | Beqolo | Poaceae | Herb | Fd | A | HG, MTF |
| *Malus domestica* | Apple | Apple | Rosaceae | Tree | Fd | A | HG |
| *Prunus persica* | Peach | Kock | Rosaceae | Shrub | Fd | A | HG |

| Scientific Name | Common Name | Local Name | Family | Growth Form | Main Purpose | Marketability | Niche |
|---|---|---|---|---|---|---|---|
| *Carica papaya* | Papaya | Papaya | Rutaceae | Shrub | Fd | A | HG |
| *Casimiroa edulis* | White sapote | Kashmir | Rutaceae | Tree | Fd | A | HG |
| *Citrus aurantiifolia* | Lemon | Lomi | Rutaceae | Shrub | Fd | A | HG |
| *Citrus medica* | Citron | Turungo | Rutaceae | Shrub | Fd | A | HG |
| *Citrus reticulata* | Mandarin orange | Mederin | Rutaceae | Shrub | Fd | A | HG |
| *Citrus sinesis* | Orange | Burtukan | Rutaceae | Shrub | Fd | A | HG |
| *Capsicum annuum* | Green pepper | Qariya | Solanaceae | Herb | Fd | A | HG |
| *Solanum lycopersicum* | Tomato | Timatim | Solanaceae | Herb | Fd | A | HG |
| *Solanum tuberosum* | Potato | Dinch | Solanaceae | Herb | Fd | A | HG |
| *Dracaena fragrans* | Chinese money tree | Serte | Dracaenaceae | Shrub | Fdr | N | HG, MCS, MTF |
| *Pennisetum purpureum* | Elephant grass | Zihon sar | Poaceae | Herb | Fdr | N | HG |
| *Justicia schimperiana* | Malabar nut tree | Timuga | Acanthaceae | Shrub | Fl | N | HG, MCS, MTF |
| *Rhus ruspolii* | N.A | Tatesa | Anacardiaceae | Shrub | Fl | N | MCS, MTF |
| *Vernonia auriculifer* | N.A | Reji | Asteraceae | Shrub | Fl | P | HG, MCS, MTF |
| *Vernonia leopoldi* | N.A | Soyoma | Asteraceae | Shrub | Fl | N | MCS |
| *Ehretia cymosa* | Murembu tree | Ulaga | Boraginaceae | Shrub | Fl | N | MCS, MTF |
| *Ritchiea albersii* | N.a | Deqo Qeleme | Capparaceae | Tree | Fl | N | HG, MCS, MTF |

| Scientific Name | Common Name | Local Name | Family | Growth Form | Main Purpose | Marketability | Niche |
|---|---|---|---|---|---|---|---|
| *Maytenus arbutifolia* | N.A | Kombolch | Celastraceae | Shrub | Fl | N | MCS, MTF |
| *Diosporyus mespiliformis* | West African ebony | Loko | Ebenaceae | Tree | Fl | N | HG, MCS, MTF |
| *Croton macrostachyus* | Broad-leaved croton | Bisana | Euphorbiaceae | Tree | Fl | N | HG, MCS, MTF |
| *Ricinus communis* | Castor bean | Gulo | Euphorbiaceae | Shrub | Fl | N | HG, MCS, MTF |
| *Blighia unijugata* | Triangle-tops | Chuchu | Fabaceae | Tree | Fl | N | MCS |
| *Entada abyssinica* | Splinter bean | Ambeltu | Fabaceae | Tree | Fl | N | TF |
| *Flacourtia indica* | Governor's plum | Akuku | Flacourtiaceae | Shrub | Fl | N | MCS |
| *Premna schimperi* | N.A | Urgesa | Lamiaceae | Shrub | Fl | N | MCS |
| *Lepidotrichilia volkensis* | N.A | Gurasade | Meliaceae | Shrub | Fl | N | MCS |
| *Trichilia dregeana* | Forest mahogany | Luya | Meliaceae | Tree | Fl | N | MCS, MTF |
| *Bersama abyssinica* | Winged bersama | Lolchinsa | Melianthaceae | Tree | Fl | N | MCS, MTF |
| *Ficus exasperata* | Sandpaper tree | Bamba | Moraceae | Tree | Fl | N | MCS |
| *Ficus glumosa* | Mountain fig | Qilinto | Moraceae | Tree | Fl | N | HG |
| *Ficus mucuso* | N.A | Kiltu | Moraceae | Tree | Fl | N | MCS |
| *Ficus ovata* | N.A | Oda | Moraceae | Tree | Fl | N | MCS, MTF |
| *Ficus sycomorus* | Mulberry fig | Lugo | Moraceae | Tree | Fl | N | MCS, MTF |
| *Ficus umbellata* | Fiddle leaf fig | Doqo | Moraceae | Tree | Fl | N | MCS, MTF |
| *Ficus vasta* | Fig tree | Ogda | Moraceae | Tree | Fl | N | HG, MCS |

| **Scientific Name** | **Common Name** | **Local Name** | **Family** | **Growth Form** | **Main Purpose** | **Marketability** | **Niche** |
|---|---|---|---|---|---|---|---|
| *Morus mesozygia* | African mulberry | Sakoo | Moraceae | Tree | Fl | N | MCS |
| *Maesa lanceolata* | False assegai | Abeyi | Myrsinaceae | Shrub | Fl | N | HG, MCS, MTF |
| *Myrsine africana* | African boxwood | Kachema | Myrsinaceae | Shrub | Fl | N | MCS |
| *Olea capensis* | Black ironwood | Gegema | Oleaceae | Tree | Fl | N | MCS, MTF |
| *Olea europaea cuspidata* | Wild olive | Ejersa | Oleaceae | Tree | Fl | P | MCS |
| *Pittosporum viridiflorum* | Cheesewood | Sole | Pittosporaceae | Shrub | Fl | N | MCS |
| *Grewia ferruginea* | N.A | Bururi | Rubiaceae | Shrub | Fl | N | MCS |
| *Clausena anisata* | Horse wood | Ulmaya | Rutaceae | Shrub | Fl | N | MCS, MTF |
| *Manilkara butugi* | N.A | Butuji | Sapotaceae | Shrub | Fl | N | TF |
| *Mimusops kummel* | Red milk wood | Kolati | Sapotaceae | Tree | Fl | N | MCS, MTF |
| *Brucea antidysenterica* | Bitter bark tree | Qomgno | Simaroubiaceae | Shrub | Fl | N | MCS |
| *Erythrina abyssinica* | Red-hot poker tree | Korch | Fabaceae | Tree | LvF | N | HG, MCS, MTF |
| *Dovyalis abyssinica* | Abyssinian gooseberry | Koshim | Flacourtiaceae | Shrub | LvF | P | HG |
| *Lepidium sativum* | Garden cress | Feto | Brassicaceae | Herb | Md | P | HG |
| *Ruta chalepensis* | Fringed rue | Tena Adam | Rutaceae | Herb | Md | P | HG |
| *Acanthus eminens* | Acanthus | Kossoru | Acanthaceae | Shrub | Mlt | N | MCS, MTF |
| *Carissa spinarum* | Carrisse | Agemsa | Apocynaceae | Shrub | Mlt | N | HG, MCS |
| *Schefflera abyssinica* | N.A | Getema | Araliaceae | Tree | Mlt | N | MCS |

| **Scientific Name** | **Common Name** | **Local Name** | **Family** | **Growth Form** | **Main Purpose** | **Marketability** | **Niche** |
|---|---|---|---|---|---|---|---|
| *Phoenix reclinata* | Wild date palm | Meti | Arecaceae | Tree | Mlt | P | HG, MCS |
| *Vernonia amygdalina* | Bitter leaf | Ebicha | Asteraceae | Shrub | Mlt | N | HG, MCS, MTF |
| *Sapium ellipticum* | Musoso | Bosoka | Euphorbiaceae | Tree | Mlt | N | HG, MCS, MTF |
| *Leucaena leucocephala* | White lead tree | Lucinea | Fabaceae | Tree | Mlt | N | HG, MCS, MTF |
| *Senna petersiana* | Eared senna | Ramso | Fabaceae | Shrub | Mlt | N | MCS |
| *Sesbania sesban* | Egyptian pea | Sesbaniya | Fabaceae | Tree | Mlt | N | HG, MTF |
| *Ficus sur (F. capensis)* | Bush fig | Arbu | Moraceae | Tree | Mlt | N | HG, MCS, MTF |
| *Ficus thonningii* | Strangler fig | Dembi | Moraceae | Tree | Mlt | N | HG, MCS |
| *Syzygium guineense* | Water pear | Bedesa | Myrtaceae | Tree | Mlt | N | HG, MCS, MTF |
| *Rubus apetalus* | Raspberry | Gora | Rosaceae | Shrub | Mlt | N | HG, MCS, MTF |
| *Polyscias fulva* | Parasol tree | Keriso | Araliaceae | Tree | Shd | N | MCS |
| *Acacia abyssinica* | Umbrella thorn | Sondi | Fabaceae | Tree | Shd | N | HG, MCS, MTF |
| *Albizia grandibracteata* | Large-leaved albizia | Alelea | Fabaceae | Tree | Shd | N | HG, MCS, MTF |
| *Albizia gummifera* | Peacock flower | Ambebesa | Fabaceae | Tree | Shd | N | HG, MCS, MTF |

| **Scientific Name** | **Common Name** | **Local Name** | **Family** | **Growth Form** | **Main Purpose** | **Marketability** | **Niche** |
|---|---|---|---|---|---|---|---|
| *Albizia schimperiana* | Forest long-pod Albizia | Dogoma | Fabaceae | Tree | Shd | N | MCS, MTF |
| *Millettia ferruginea* | N.A | Sotelu | Fabaceae | Tree | Shd | N | HG, MCS |
| *Coriandrum sativum* | Coriander | Dimblal | Apiaceae | Herb | SpAdt | P | HG |
| *Ocimum basilicum* | Sweet Basil | Besobila | Lamiaceae | Herb | SpAdt | P | HG |
| *Rhamnus prinoides* | Dogwood | Gesho | Rhamnaceae | Shrub | SpAdt | A | HG |
| *Capsicum frutescens* | Chilli pepper | Berbere | Solanaceae | Herb | SpAdt | A | HG |
| *Aframomum corrorima* | Ethiopian cardamom | Korerima | Zingiberaceae | Herb | SpAdt | A | HG |
| *Curcuma longa* | Turmeric | Erid | Zingiberaceae | Herb | SpAdt | A | HG |
| *Zingiber officinale* | Ginger | Zinjible | Zingiberaceae | Herb | SpAdt | A | HG |
| *Catha edulis* | Khat | Khat | Celastraceae | Shrub | Stm | A | HG, MTF |
| *Coffea arabica* | Coffee | Buna | Rubiaceae | Shrub | Stm | A | HG, MCS |
| *Saccharum officinarum* | Sugarcane | Shenkora | Poaceae | Herb | Swt | A | HG |
| *Cordia africana* | Large-leaved cordia | Wodesa | Boraginaceae | Tree | Tb | P | HG, MCS, MTF |
| *Casuarina equisetifolia* | Australian beefwood | Arze libanos | Casuarinaceae | Tree | Tb | P | HG |
| *Cupressus lustanica* | Mexican cypress | Yeferenge tid | Cupressaceae | Tree | Tb | P | HG, MCS, MTF |
| *Bridelia micrantha* | Coast gold-leaf | RigaRaba | Euphorbiaceae | Tree | Tb | N | HG, MCS, MTF |

| **Scientific Name** | **Common Name** | **Local Name** | **Family** | **Growth Form** | **Main Purpose** | **Marketability** | **Niche** |
|---|---|---|---|---|---|---|---|
| *Erythrina brucei* | N.A | Welensu | Fabaceae | Tree | Tb | N | HG, MCS |
| *Ekebergia capensis* | Cape ash | Somboo | Meliaceae | Tree | Tb | N | MCS, MTF |
| *Trilepisium madagascariense* | False-fig | Gogee | Moraceae | Tree | Tb | P | MCS |
| *Eucalyptus grandis* | Flooded gum | Bahir zaf | Myrtaceae | Tree | Tb | A | HG, MCS, MTF |
| *Olea welwitschii* | Elgon olive | Beha | Oleaceae | Tree | Tb | P | MCS, MTF |
| *Grevillea robusta* | Australian silver oak | Gravilia | Proteaceae | Tree | Tb | P | HG, MCS, MTF |
| *Prunus africana* | African almond | Omi | Rosaceae | Tree | Tb | N | HG, MCS, MTF |
| *Pouteria adolfi-friederici* | Aningeria | Qerero | Sapotaceae | Tree | Tb | P | MCS, MTF |
| *Celtis africana* | White stinkwood | Cheyi | Ulmaceae | Tree | Tb | N | MCS, MTF |

*N.a = Not available; Main purpose: Fd= food, Fdr= fodder, Fl= fuel, Tb= Timber, SpAdv= spice, condiment and additives Shd= shade Mlt= multiple use Md= medicinal, Lvf= live fence; Marketability: A= Actively-marketed species, P= passive/potentially-marketed species N= non-market species; Nich: HG= homegarden; MCS= multistorey-coffee-system; MTF= multipurpose-trees-on-farmland.*

## Appendix 2. Useful trees assessing data collection sheet: Household survey

| | | | | | |
|---|---|---|---|---|---|
| 1. Intro | answer | (Please | | | |
| 1.1 Date of interview | | | | | |
| 1.2 Name of Woreda | | | | | |
| 1.3 Name of Kebele | | | | | |
| 1.4 Name of zone/village | | | | | |
| 1.5 Code | | | | | |
| 1.6 GPS coordinates | X | Y | | | |
| 1.7 altitude | | | | | |
| 1.8 Name of interviewer | | | | | |
| 2. Basic information about the | answer | (Please | | | |
| 2.1 Name of interviewee: | | | | | |
| 2.2 Age | | | | | |
| 2.3 Place of birth of the | | | | | |
| 2.4 Sex: Male=1; Female= | | | | | |
| 2.5 Level of education of | | | | | |
| 2.6 Ethnicity: | | | | | |
| 2.7 Religion: | | | | | |
| 2.8 Settlement history | | | | | |
| 3. Household characteristics | | | | | |
| 3.1 Total household size | | | | | |
| 3.2 Number of children | | | | | |
| 3.3 Number of non-breast | | | | | |
| 3.4 Number and type of | | | | | |
| 3.4.1 Number of thatched houses | | | | | |
| 3.4.2 Do you have a house of | | | | | |
| 4. Farming systems, crops and | answer | (Please | | | |
| 4.1 land holding | | | | | |
| 4.1.1 Total size of farmland (in timad | | | | | |
| 4.1.1.1 Number of farm plots | | | | | |
| 4.1.2 What is the total size of your | | | | | |
| 4.1.2.1Number of coffee agroforest forest | | | | | |
| 4.1.3. Total area of homegarden (in timad): | | | | | |
| 4.2 Main agroforestry food crops and their quantities | | | | | |
| Type of crop | Yield per year (in | | Cause for yield | | |
| | Now | 5 years | | | |
| | | | | | |
| | | | | | |
| 5. Cash income and expenditures | | | | | |
| 5.1 Marketplaces | | | | | |
| Name of marketplace(according to | Main | Main | Means of | Length | |
| | | | | | |
| | | | | | |
| Source of income | | | | | |
| 5.2 Income in one year | Income | Common | | | |
| 5.2.1 Selling of coffee | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| 5.2.2 Selling of maize | | | | | |
| 5.2.3 Selling of Teff | | | | | |
| 5.2.4 Selling of other agricultural products | | | | | |
| Name: | | | | | |
| | | | | | |
| | | | | | |
| 5.2.5 Selling of livestock | | | | | |
| 5.2.6 Selling of honey | | | | | |
| 5.2.7 Employment in others' farms | | | | | |
| 5.2.8 Employment by coffee processors | | | | | |
| 5.2.9 Non-farm employment/ outside | | | | | |
| 5.2.10 Remittances from other family | | | | | |
| 5.2.11 Remittances from the state, | | | | | |
| 5.2.12 Other income, Please specify: | | | | | |
| 5.3 Expenditure in one year | Types of | Expenditur | | | |
| Clothe | | | | | |
| HH lighting energy | | | | | |
| Medicine | | | | | |
| HH consumption | | | | | |
| | | | | | |
| | | | | | |
| 5.3.1 Taxes | | | | | |
| 5.3.2 Expenditures for school materials | | | | | |
| 5.3.3 Fertilizer | | | | | |
| 5.3.4 Seeds | | | | | |
| 5.3.5 Insecticides | | | | | |
| 5.3.6 Farm labor | | | | | |
| 5.3.7 Others (Please specify): | | | | | |
| | | | | | |
| 6. Coping with food insecurity | answer | (Please | | | |
| 6.1 Has your household ever | | | | | |
| 6.2 If your answer to Q5.1 is yes, which | | | | | |
| 6.3 If your answer to Q5.1 is yes, what are the three main coping strategies to pass through the problematic months? (please list according to importance) | | | | | |
| | | | | | |
| | | | | | |
| 6.4 How do you financially overcome | | | | | |
| 7. Useful plants spices of the framing system | | | | | |
| Local Species name | Main use | Other uses | Edibility | Marke | Obtai |
| | | | | | |
| | | | | | |

## Appendix 3. Useful trees assessing data collection sheet: Plot inventory

Woreda:____ Kebele:____ Village/Zone_____ altitude_______X________ Y________

| HH No | Niche | Species name | Primary use | Edibility | Edible part | Marketability | Remark |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | | | | |

## Appendix 4. Household/individual survey to assess the Food security, dietary pattern and nutritional status of smallholding framing households of Yayu.

### 1 BASIC DATA

#### 1.1 Household head's

Woreda: __________Kebele: ________Village/Zone : __________
i, Name: ____________________________ ii, Sex (M/F): ____ iii, Age: ____
iv, Education:________
v, Place of birth: ___________________ vi, Ethnicity: ______________ vii, Religion: ________

#### 1.2 Spouse's info

i, Name: ____________________________ ii, Sex (M/F): ____ iii, Age: ____
iv, Education:________
v, Place of birth: ___________________ vi, Ethnicity: ______________ vii, Religion: ________

#### 1.3 Family size

a. Total number of people living in the house: __________ Male: _____________ Female:____________
b. Number of people (older than 15) in the house: __________ Male: ___________ Female:____________
c. Number of non-breast feeding children younger than 5 years old : __________

#### 1.4 Household's target individuals roster and anthropometric measurement

| Target | Full Name | Mother's name | Date of birth (MM/YY) or Age | Sex F/M |
|---|---|---|---|---|
| NBF child 1 | | | | |
| NBF child 2 | | | | |
| WAR 1 | | | | |

### 2 FOOD (IN)SECURITY STATUS

2.1. HHS (for the last month food history)

| NO | QUESTION | RESPONSE OPTIONS | Code (0 = No<br>1 = Yes<br>9 = Don't know) |
|---|---|---|---|
| 1 | In the past four weeks, was there ever no food to eat of any kind in your household because of lack of resources to get food? (at least once) | 0 = No (skip to Q8)<br>1 = Yes | |
| 1a | How often did this happen? | 1 = Rarely (once or twice in the past four weeks)<br>2 = Sometimes (three to ten times in the past four weeks) | |

| | | | |
|---|---|---|---|
| | | 3 = Often (more than ten times in the past four weeks) | |
| 2 | In the past four weeks, did you or any household member go to sleep at night hungry because there was not enough food? | 0 = No (skip to Q9)<br>1 = Yes | |
| 2a | How often did this happen? | 1 = Rarely (once or twice in the past four weeks)<br>2 = Sometimes (three to ten times in the past four weeks)<br>3 = Often (more than ten times in the past four weeks) | |
| 3 | In the past four weeks, did you or any household member go a whole day and night without eating anything because there was not enough food? | 0 = No (questionnaire is finished)<br>1 = Yes | |
| 3a | How often did this happen? | 1 = Rarely (once or twice in the past four weeks)<br>2 = Sometimes (three to ten times in the past four weeks)<br>3 = Often (more than ten times in the past four weeks) | |

### 2.2. HFIAS (for the last month food history)

| NO | QUESTION | RESPONSE OPTIONS | CODE |
|---|---|---|---|
| 1 | In the past four weeks, did you worry that your household would not have enough food? | 0 = No (skip to Q2)<br>1=Yes | |
| 1a | How often did this happen? | 1 = Rarely (once or twice in the past four weeks)<br>2 = Sometimes (three to ten times in the past four weeks)<br>3 = Often (more than ten times in the past four weeks) | |
| 2 | In the past four weeks, were you or any household member not able to eat the kind of foods you preferred because of a lack of resources? | 0 = No (skip to Q3)<br>1=Yes | |

| | | | |
|---|---|---|---|
| 2a | How often did this happen? | 1 = Rarely (once or twice in the past four weeks)<br>2 = Sometimes (three to ten times in the past four weeks)<br>3 = Often (more than ten times in the past four weeks) | |
| 3 | In the past four weeks, did you or any household member have to eat a limited variety of foods due to a lack of resources? | 0 = No (skip to Q4)<br>1 = Yes | |
| 3a | How often did this happen? | 1 = Rarely (once or twice in the past four weeks)<br>2 = Sometimes (three to ten times in the past four weeks)<br>3 = Often (more than ten times in the past four weeks) | |
| 4 | In the past four weeks, did you or any household member have to eat some food that you really did not want to eat because of a lack of resources to obtain other types of food? | 0 = No (skip to Q5)<br>1 = Yes | |
| 4a | How often did this happen? | 1 = Rarely (once or twice in the past four weeks)<br>2 = Sometimes (three to ten times in the past four weeks)<br>3 = Often (more than ten times in the past four weeks) | |
| 5 | In the past four weeks, did you or any household member have to eat a smaller meal than you felt you needed because there was not enough food? | 0 = No (skip to Q6)<br>1 = Yes | |
| 5a | How often did this happen? | 1 = Rarely (once or twice in the past four weeks)<br>2 = Sometimes (three to ten times in the past four weeks)<br>3 = Often (more than ten times in the past four weeks) | |

### 2.3. Dietary diversity (for the last 24 hours)

Tick the Target 1. Households ☐ 2. NBF childe ☐ 3. WAR ☐

Respondent's (child's primary feeder/ caregiver) information

Name: ______Relation to the Child ______ Education:_____ Place of birth: ________

Ethnicity: ___ Religion______

| | Name of the | Ingredients | Daily | Where |
|---|---|---|---|---|
| Breakfast to Lunch | | | | |
| Food/drink 1 | | | | |
| | | Ingredient 1 | | |
| | | Ingredient 2 | | |
| Food/drink 2 | | | | |
| | | Ingredient 1 | | |
| Lunch to dinner | | | | |
| Food/drink 1 | | | | |
| Dinner onward | | | | |
| Food/drink 1 | | | | |

### 2.5. FOOD COSUMPTION FREQUENCY SHEET (SEVEN DAYS)

Tick the target 1. Household ☐ 2. NBF childe ☐ 3. WAR ☐

Fill in the frequency of consumption (on household level) of each food item in the last either seven days as a figure in frequency per day, per week, or in form of an x in rare or never. Rare is defined as a frequency less than once a week.

| **Food item** | **Frequency of consumption** | | | | **Source** |
|---|---|---|---|---|---|
| | **per day** | **Per week** | **rare** | **never** | 1 = produced, 2 = collected 3 = purchased, 4 = other, specify |
| **Cereals** | | | | | |
| Maize | | | | | |
| Sorghum | | | | | |
| Finger millet | | | | | |
| Teff | | | | | |
| Rice | | | | | |
| Barley | | | | | |
| Wheat | | | | | |
| | | | | | |
| **Roots, tubers, plantain** | | | | | |
| Cassava | | | | | |
| Sweet potatoes | | | | | |
| Round potatoes | | | | | |
| Godere | | | | | |
| Enset | | | | | |
| Anchote | | | | | |
| Red beet | | | | | |
| | | | | | |
| **Legumes** | | | | | |
| Beans | | | | | |
| Peas | | | | | |
| Chick pea | | | | | |

| **Food item** | **Frequency of consumption** | | | | **Source** |
|---|---|---|---|---|---|
| | **per day** | **Per week** | **rare** | **never** | 1 = produced, 2 = collected 3 = purchased, 4 = other, specify |
| Grass pea | | | | | |
| Lentils (Misr) | | | | | |
| Haricot bean (Adengure) | | | | | |
| Soybeans (Akuri ater) | | | | | |
| Boloke | | | | | |
| | | | | | |
| **Nuts and seeds** | | | | | |
| Groundnuts (ocholoni) | | | | | |
| | | | | | |
| **Meat, poultry, eggs** | | | | | |
| Beef | | | | | |
| Goat | | | | | |
| Sheep-lamb | | | | | |
| Wild game meat e.g. procupine | | | | | |
| Poultry-chicken/duck | | | | | |
| Liver | | | | | |
| Other organ meat | | | | | |
| Eggs | | | | | |
| | | | | | |
| **Fish and seafood** | | | | | |
| Fresh-water fish | | | | | |
| Sardines | | | | | |
| | | | | | |
| **Milk and milk products** | | | | | |
| Cow's milk (whole) | | | | | |
| Yoghurt | | | | | |
| Butter/lard | | | | | |
| Arera | | | | | |
| Cheese | | | | | |
| | | | | | |
| **Oils and fat** | | | | | |
| Sunflower oil | | | | | |
| Palm oil | | | | | |
| Niger oil | | | | | |
| | | | | | |

| **Food item** | **Frequency of consumption** | | | | **Source** |
|---|---|---|---|---|---|
| | **per day** | **Per week** | **rare** | **never** | 1 = produced, 2 = collected 3 = purchased, 4 = other, specify |
| **Vegetables** | | | | | |
| Abrango | | | | | |
| Rafu | | | | | |
| Red beet leaves | | | | | |
| Carrots | | | | | |
| Pumpkin fruit | | | | | |
| Tomatoes | | | | | |
| Abrango | | | | | |
| Garlic | | | | | |
| Onion | | | | | |
| Tikil Gomen | | | | | |
| Selata | | | | | |
| Other indigenous vegetable | | | | | |
| | | | | | |
| **Fruits** | | | | | |
| Oranges or lemon, Mederin | | | | | |
| Mangoes | | | | | |
| Roman | | | | | |
| Jackfruit | | | | | |
| Bananas | | | | | |
| Pineapple | | | | | |
| Papaya | | | | | |
| Avocado | | | | | |
| Kashmir | | | | | |
| Tringo | | | | | |
| Gishta | | | | | |
| Kock | | | | | |
| Other native fruits | | | | | |
| | | | | | |
| **Beverages** | | | | | |
| Keneto | | | | | |
| All soda drinks | | | | | |
| Coffee | | | | | |
| Tea | | | | | |
| Juice | | | | | |
| Milk | | | | | |
| Local brew Tela | | | | | |
| Beer | | | | | |

| Food item | Frequency of consumption | | | | Source |
|---|---|---|---|---|---|
| | per day | Per week | rare | never | 1 = produced, 2 = collected<br>3 = purchased, 4 = other, specify |
| Areke | | | | | |
| Other beverages (mention) | | | | | |

### 2.6. FOOD FREQUENCY SHEET (4 WEEKS)

Tick the target 1. Household ☐ 2. NBF childe ☐ 3. WAR ☐

Fill in the frequency of consumption (on household level) of each food item in the last four weeks either as a figure in frequency per day, per week, per month or in form of an x in rare or never. Rare is defined as a frequency less than once a month.

| Food item | Frequency of consumption | | | | | Source |
|---|---|---|---|---|---|---|
| | per day | per week | Per months | rare | never | 1 = produced, 2 = collected<br>3 = purchased, 4 = other, specify |
| **Cereals** | | | | | | |
| Maize | | | | | | |
| Sorghum | | | | | | |
| Finger millet | | | | | | |
| Teff | | | | | | |
| Rice | | | | | | |
| Barley | | | | | | |
| Wheat | | | | | | |
| | | | | | | |
| **Roots, tubers, plantain** | | | | | | |
| Cassava | | | | | | |
| Sweet potatoes | | | | | | |
| Round potatoes | | | | | | |
| Godere | | | | | | |
| Enset | | | | | | |
| Anchote | | | | | | |
| Red beet | | | | | | |
| | | | | | | |
| **Legumes** | | | | | | |
| Beans | | | | | | |
| Peas | | | | | | |
| Chick pea | | | | | | |
| Grass pea | | | | | | |
| Lentils (Misr) | | | | | | |

| **Food item** | **Frequency of consumption** | | | | | **Source** |
|---|---|---|---|---|---|---|
| | **per day** | **per week** | **Per months** | **rare** | **never** | 1 = produced, 2 = collected<br>3 = purchased, 4 = other, specify |
| Haricot bean (Adengure) | | | | | | |
| Soybeans (Akuri ater) | | | | | | |
| Boloke | | | | | | |
| **Nuts and seeds** | | | | | | |
| Groundnuts (ocholoni) | | | | | | |
| | | | | | | |
| **Meat, poultry, eggs** | | | | | | |
| Beef | | | | | | |
| Goat | | | | | | |
| Sheep-lamb | | | | | | |
| Wild game meat eg. porcupine | | | | | | |
| Poultry-chicken/duck | | | | | | |
| Liver | | | | | | |
| Other organ meat | | | | | | |
| Eggs | | | | | | |
| | | | | | | |
| **Fish and seafood** | | | | | | |
| Fresh-water fish | | | | | | |
| Sardines | | | | | | |
| | | | | | | |
| **Milk and milk products** | | | | | | |
| Cow's milk (whole) | | | | | | |
| Yoghurt | | | | | | |
| Butter/lard | | | | | | |
| Arera | | | | | | |
| Cheese | | | | | | |
| | | | | | | |
| **Oils and fat** | | | | | | |
| Sunflower oil | | | | | | |
| Palm oil | | | | | | |

| **Food item** | **Frequency of consumption** | | | | | **Source** |
|---|---|---|---|---|---|---|
| | **per day** | **per week** | **Per months** | **rare** | **never** | 1 = produced, 2 = collected<br>3 = purchased, 4 = other, specify |
| **Niger oil** | | | | | | |
| | | | | | | |
| | | | **Vegetables** | | | |
| Abrango | | | | | | |
| Rafu | | | | | | |
| Red beet leaves | | | | | | |
| Carrots | | | | | | |
| Pumpkin fruit | | | | | | |
| Tomatoes | | | | | | |
| Abrango | | | | | | |
| Garlic | | | | | | |
| Onion | | | | | | |
| Tikil Gomen | | | | | | |
| Selata | | | | | | |
| Other indigenous vegies | | | | | | |
| | | | | | | |
| | | | **Fruits** | | | |
| Oranges or lemon, Mederin | | | | | | |
| Mangoes | | | | | | |
| Roman | | | | | | |
| Jackfruit | | | | | | |
| Bananas | | | | | | |
| Pineapple | | | | | | |
| Papaya | | | | | | |
| Avocado | | | | | | |
| Kashmir | | | | | | |
| Tringo | | | | | | |
| Gishta | | | | | | |
| Kock | | | | | | |
| Other native fruits | | | | | | |
| | | | | | | |
| | | | **Beverages** | | | |
| Keneto | | | | | | |

| **Food item** | **Frequency of consumption** | | | | | **Source** |
|---|---|---|---|---|---|---|
| | **per day** | **per week** | **Per months** | **rare** | **never** | 1 = produced, 2 = collected<br>3 = purchased, 4 = other, specify |
| All soda drinks | | | | | | |
| Coffee | | | | | | |
| Tea | | | | | | |
| Juice | | | | | | |
| Milk | | | | | | |
| Local beer Tela | | | | | | |
| Beer | | | | | | |
| Areke | | | | | | |
| Other beverages (mention) | | | | | | |

### 2.7. ANTHROPOMETRIC MEASUREMENTS

| **Target** | **Date of birth (MM/YY) or Age** | **Sex F/M** | **Height in cm** | **Weight in kg** | **Wiest in cm** | **Arm circumference in cm** | **Head Circumference in cm** | **Does Child Have Edema?** | **Pregnancy status** | **Health problem** |
|---|---|---|---|---|---|---|---|---|---|---|
| **Woman** | | ▨ | | | | ▨ | ▨ | ▨ | | |
| **Child** | | | | | | | | | ▨ | |

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