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Local Alternatives to Local Problems

The Contribution of Agroforestry System By-products to Food and Nutrition Security of Communities in Southwestern Ethiopia

DANIEL CALLO-CONCHA, OMARSHERIF M. JEMAL, AND HABTAMU SEYOUM ARAGAW

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Local Alternatives to Local Problems: The Contribution of Agroforestry System By-products to Food and Nutrition Security of Communities in Southwestern Ethiopia

Daniel Callo-Concha,[1] University of Bonn, Germany
Omarsherif M. Jemal, Ethiopian Biodiversity Institute, Ethiopia
Habtamu Seyoum Aragaw, Ethiopian Institute of Agricultural Research, Ethiopia

Abstract: The montane rainforest of southwestern Ethiopia, coffee's centre of origin, is dominated by multifunctional and multi-species agroforestry systems that broadly benefit farmer livelihoods. Although economic and environmental advantages are widely praised, the contributions of these systems to food and nutrition are mostly unaccounted. Hence, we evaluated the current and potential roles of agroforestry systems in strengthening the food and nutrition security of smallholder households by: (i) determining the agroforestry systems and identifying nutritionally valuable species occurring there, (ii) evaluating the householders' nutritional status, and (iii) matching nutritional demands with the nutrients offered by the agroforestry systems. Mixed methods were applied including characterization of the households' agroforestry plots, dietary and biometry assessment, and biochemical analyses. FAO suggested in-situ policies to improve food and nutrition security include facilitating access to foods and nutrients, making available food rich in important micronutrients, improving sanitation and health conditions, and increasing consumer purchasing power. This study directly targets (i) and (ii) by identifying underutilized potentially edible species, evaluating their nutritional content, and estimating agreement with local demands, and marginally (iii) and (iv) by eventual subsequent improved living conditions and potential additional income.

Keywords: Hidden Hunger, Homegarden, Multi-Storey Coffee System, Multipurpose Trees on Farmlands, Potentially Edible Plants, Yayu Biosphere Reserve

Introduction

Today, food production is faced with a broad array of challenging conditions, i.e., environmental degradation, variable weather, unequal technological means, increasing bias towards market involvement, etc., which influence the food system globally and particularly in developing countries (FAO 2009; FAO et al. 2015; UN-DESA-PD 2015). Concurrent changes in demography and eating habits still cause hunger, and have triggered malnutrition in the form of micronutrient deficiency, and undernutrition and over nutrition, the latter expressed as overweight and obesity (Eckhardt 2006; Popkin, Adair, and Ng 2012). These burdens mostly target people in low- and middle-income countries of southern Asia and sub-Saharan Africa, where about 800 million people are undernourished, and over two billion suffer from micronutrient deficiencies (FAO et al. 2015). Known as "hidden hunger," the lack of vitamins and minerals in diets or the inadequate intake of these micronutrients may result in different types of malnutrition, such as iron-deficiency, anaemia, and vitamin-A deficiency, which seriously harm children's development and hamper adults' performance (Arcand 2001; Stein and Qaim 2007; Balarajan et al. 2011; Biesalski 2013; FAO et al. 2015).

Conventional approaches to improve production and productivity to reduce malnutrition in sub-Saharan Africa have not necessarily been effective. For instance, augmenting the production

[1] Corresponding Author: Daniel Callo-Concha, Genscheralle 3, Department of Ecology and Natural Resources Management, Center for Development Research (ZEF), University of Bonn, Bonn, 53113, Germany. email: d.callo-concha@uni-bonn.de

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of staple crops made more carbohydrates available, which has not resulted in improved overall food security (WHO 2003). As nutrient-rich food is especially sensitive to price variations (Caraher and Cowburn 2005), poor farmers tend to sacrifice the consumption of more nutritious foods by maintaining their stocks of staples (FAO et al. 2013).

Most of these farmers still rely on food produced locally for consumption (Funk and Brown 2009; Lamb 2000). For this purpose, smart farming systems capable of addressing food and nutrient demands, and also (by)products of market value with a minimal impact on the environment, are praised as valuable alternatives (Pretty and Bharucha 2014; Lang and Heasman 2015; FAO 2017). Among others, agroforestry is promoted as being capable of addressing the food and nutrition security of smallholder farming households, especially in impoverished agrarian countries (Frison, Cherfas, and Hodgkin 2011; Bishaw et al. 2013; Ickowitz et al. 2014; Jamnadass et al. 2013; Mbow et al. 2014; Dawson et al. 2014). Nonetheless, its degree of impact is known to be site specific, as the inherent variability among agroforestry systems requires, ahead of their implementation, understanding the local conditions and their trade-offs (Raintree and Warner 1986; Franzel and Scherr 2002; Jose 2009; Mbow et al. 2014).

Food and nutrition security is still a major issue in Ethiopia. Two decades ago, Ethiopia was associated with persistent famines (von Braun and Olofinbiyi 2007; Block and Webb 2001). At present, Ethiopians consume on average 2,200 kcal/day (FAO 2015), but it is estimated that more than thirty million undernourished people live in the country. That makes Ethiopia the country with the fourth highest number of undernourished people in the world (Endalew, Muche, and Tadesse 2015; FAO et al. 2015). The underlying reason is assumed to be the traditional, low-tech, and rain-fed agriculture (Mengistu, Regassa, and Yusufe 2009; Endalew, Muche, and Tadesse 2015), resulting in productivity that is among the lowest in the world (Devereux and IDS Sussex 2000; MoFED 2006; FAO et al. 2015).

Different government initiatives, e.g., Agricultural Development-Led Industrialization, Productive Safety Net Program, or Climate-Resilient Green Economy, consider agroforestry as a crosscutting element (FDRE 1996, 2003). But, as mentioned before, agroforestry practices are highly site and problem specific, which requires *ad-hoc* studies on their feasibility. For example, the Enset-coffee-based homegarden (Guwaro) is a complex multispecies production system practiced around the homestead, widespread in southern Ethiopia and recognized as a highly performing farming practice in social, economic, and ecological terms (Asfaw 2002; Tesfaye, Wiersum, and Bongers 2010; Sahilu 2017; Jemal, Callo-Concha, and van Noordwijk 2018).

The traditional agroforestry systems of Yayu in southwestern Ethiopia are widespread and have been proven capable of sustaining the livelihoods of local populations while maintaining environmental integrity (Assefa 2010; Senbeta et al. 2013; Jemal and Callo-Concha 2017). The ecological, agronomical, social, and even economic aspects have been studied, but little attention was given to their food and nutritional roles (Jemal and Callo-Concha 2017). Hence, this study aims to (1) identify and characterize the Yayu agroforestry systems and relevant potentially edible and other multipurpose species, (2) assess the food and nutrition security status of the smallholder households, and (3) analyse the nutritional value of selected edible species to potentially supply household demands.

Materials and Methods

Study Area

The study was conducted in Yayu, located in the Illulabor province, Oromia regional state of Ethiopia, 560 km west of Addis Ababa, 8 21’–8 26’N and 35 45’–36 3’E (Figure 1). Yayu lies in the Eastern Afromontane Biodiversity Hotspot with altitudes varying from 1200 to 2000 m.a.s.l. The climate is hot and humid, the mean annual temperature is 20°C varying between the average extremes of 12°C and 29°C. The area exhibits a unimodal rainfall pattern with a rainy season between May and October and a mean annual precipitation of 2100 mm, but with high variability from year to year (Gole et al. 2008; World Bank Group 2017). Dominant soil groups include nitosols, acrisols, vertisols, and cambisols (Tafesse 1996).

The area was registered by UNESCO as the Yayu Coffee Forest Biosphere Reserve in 2010, and was classified into three concentric zones, i.e. core (ca. 28,000 ha), buffer (ca. 22,000 ha), and transition (ca. 118,000 ha) zones (Gole et al. 2009). In the outer transition and buffer zones, economic activities are allowed varying from coffee production to settlements (Gole et al. 2009). In 2007, around 310,000 people lived in the six Woreda (political unit) comprising the Yayu biosphere reserve, out of which 90 percent lived in rural areas (Figure 1) (CSA 2007).

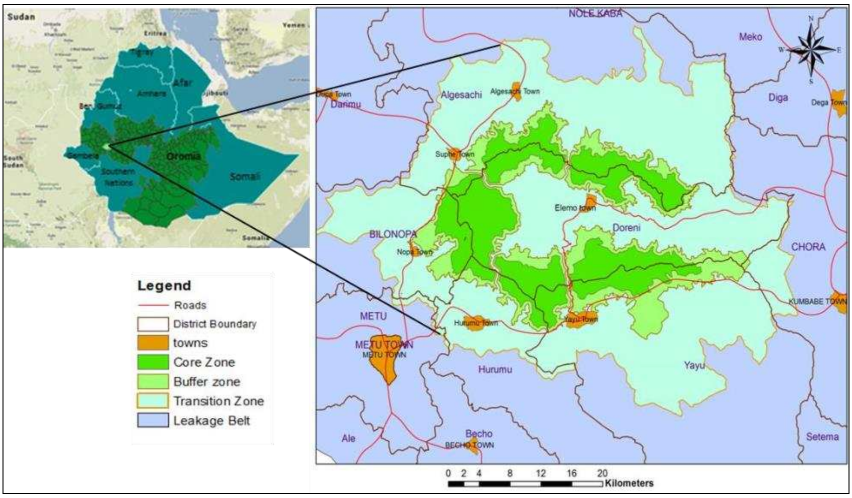

Figure 1: Location of the Yayu Coffee Forest Biosphere Reserve
Source: Adapted by the Authors from Gole et al. 2009

Methods

This study aimed to bridge Yayu farmer nutritional demands with the biophysical basis to address it. It undertook this in three successive steps, by: (i) identifying and evaluating the existing local farming (agroforestry; predominant in the region) practices, the species existing in them, and their utilities; (ii) determining the food and nutritional status of the householders; and (iii) assessing the nutritional contents of selected valuable species identified.

Local Agroforestry Practices, Their Species, and Utilities

A total of 300 households were selected by applying a multi-stage random sampling, based on their proximity to the forest and markets. Data were collected using semi-structured interviews and field observations. The dominant agroforestry practices (AFP) were determined from the widely adopted classification by Nair (1985). The species composition of each AFP was recorded by consulting local farmers, and verified by a local taxonomist and specific literature (Mooney 1963; Bekele 2007). The species were identified and classified into ten main utility groups (Méndez, Lok, and Somarriba 2001). The food edibility potential was determined by classifying all edible species into two groups, i.e., “active-food” and “potentially-edible” species (Bekele 2007). Finally, the active-food species were re-classified into ten plant-derived food groups out of fourteen, as the other four refer to animal-based food groups only (Kennedy, Ballard, and Dop 2011).

Determination of Household Food and Nutrition Status

140 households were subsampled from the original 300, by counting the two groups nutritionally most vulnerable, i.e., non-breast-fed children aged twelve to fifty-nine months, and non-pregnant

and non-lactating women of reproductive age (WFP-VAM 2008; WHO 2008). These were systematically assessed by female health extension workers to determine the food and nutrition status in three steps. First, food (in)security was assessed via proxies, namely the Household Food Insecurity Access Scale (HFIAS) (Coates, Swindale, and Bilinsky 2007), and the Household Dietary Diversity Score (HDDS) (Swindale and Bilinsky 2006). Secondly, using a seven-day food consumption score (FCS), the weekly consumption trend of foods rich in protein, vitamin A, and iron was evaluated (WFP-VAM 2008; WHO 2008; FAO and FHI 360 2016). Thirdly, the nutritional status of the two target groups was measured, namely stunting, wasting, and underweight for the children, and body mass index (BMI) for the women through anthropometric measurements such as weight, height, and age (WHO 2006; FANTA 2016). Data collection took place between December 2014 and August 2016 in order to cover the two farming seasons with food surplus and food shortage.

Analyses of the Nutritional Value of Underutilized Edible Species

Three successive screenings were implemented: (i) all useful species growing in the AFP, (ii) all edible species, by consulting knowledgeable individuals (n=40), and (iii) the species available at the time of the sampling (seasonal availability). Finally, twelve underutilized edible species were selected (Table 1). Between 250 and 1000g of the edible part of each species were harvested, packed in ice boxes, and transported ca. 200 km to Jimma University for laboratory analyses. The proximate analysis included crude protein and energy contents (AOAC 2003). Iron content was quantified using atomic absorption spectrophotometer (AOAC 2003), and the pro-vitamin-A (beta-carotene) contents were measured according to Sadler, Davis, and Dezman (1990).

Results

Local Agroforestry Practices, Their Species, and Utility Groups

Three major AFPs were identified, i.e., homegarden (HG), multi-storey coffee system (MCS), and multi-purpose trees on farmlands (MTF). Of the households, 97 percent, 93 percent, and 85 percent had MCS, HG, and MTF, respectively, and more than 80 percent all three. Regarding their areas, on average HGs are the smallest with an average of 0.1 ha, and MCSs the largest with an average of 2.5 ha (Figure 2A). Each AFP has a primary purpose, i.e. MTF is mainly for food production, MCS for income generation, and HG for both (Figure 2B). 127 useful plant species were identified in all the AFP, with 42.5 percent trees, 26 percent shrubs, and 31.5 percent herbs correspondingly. The latter were absent in MCS (Figure 2C). Ten utility groups were identified. All utility groups were present in all three AFP except "food," "spices, condiments, and additives," and "coffee shade" (Figure 2D).

In all three AFPs, eighty edible species were found out of which fifty-five were identified as active food crops, hence primarily cultivated for household food supply, and twenty-five as potentially edible but currently not cultivated. Nearly 60 percent (52) of the edible species identified in the HGs were active food crops, which was the highest proportion recorded. In MCSs only one edible species was identified—coffee—the lowest in all systems, but MCSs also showed the highest proportion of potentially edible species (>30%), suggesting an untapped potential for exploitation (Figure 2E). After re-categorizing the active food crops into ten food groups (Kennedy et al. 2011), all food groups were only found in the HG, while MTF had only two food groups ("cereals" and "legumes"), and MCS only one ("spices, condiments, beverages") (Figure 2F). A detailed assessment of the potential of Yayu agroforestry practices for local householder nutrition was made by Jemal, Callo-Concha, and van Noordwijk (2018).

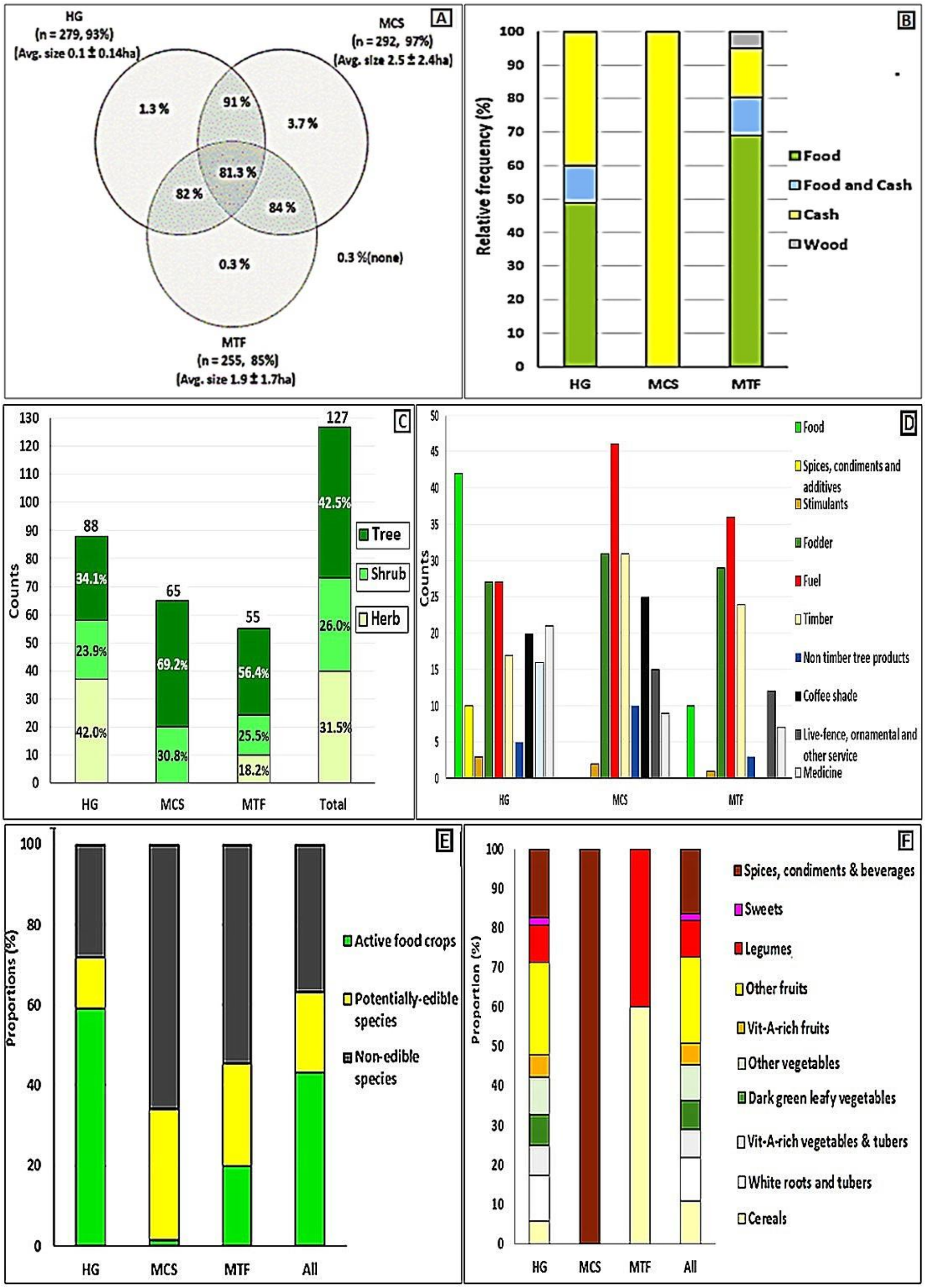

Figure 2: Major Forms, Floristic Composition, Utilities, and Food Production Potential of Local Agroforestry Practices in Yayu: 2A. Average Size and Relative Frequency. 2B. Relative Frequency of Main Purpose of Management. 2C. Count and Proportion of Species and Growth Habits. 2D. Species Count under Ten Utility Groups. 2E. Proportion of Edibility Categories across Major Practices. 2F. Proportion of Food Groups under Active Food Crops Grown across Practices. Homegardens (HG), Multi-Storey Coffee Systems (MCS), and Multipurpose Trees on Farmlands (MTF).
Source: Jemal 2018

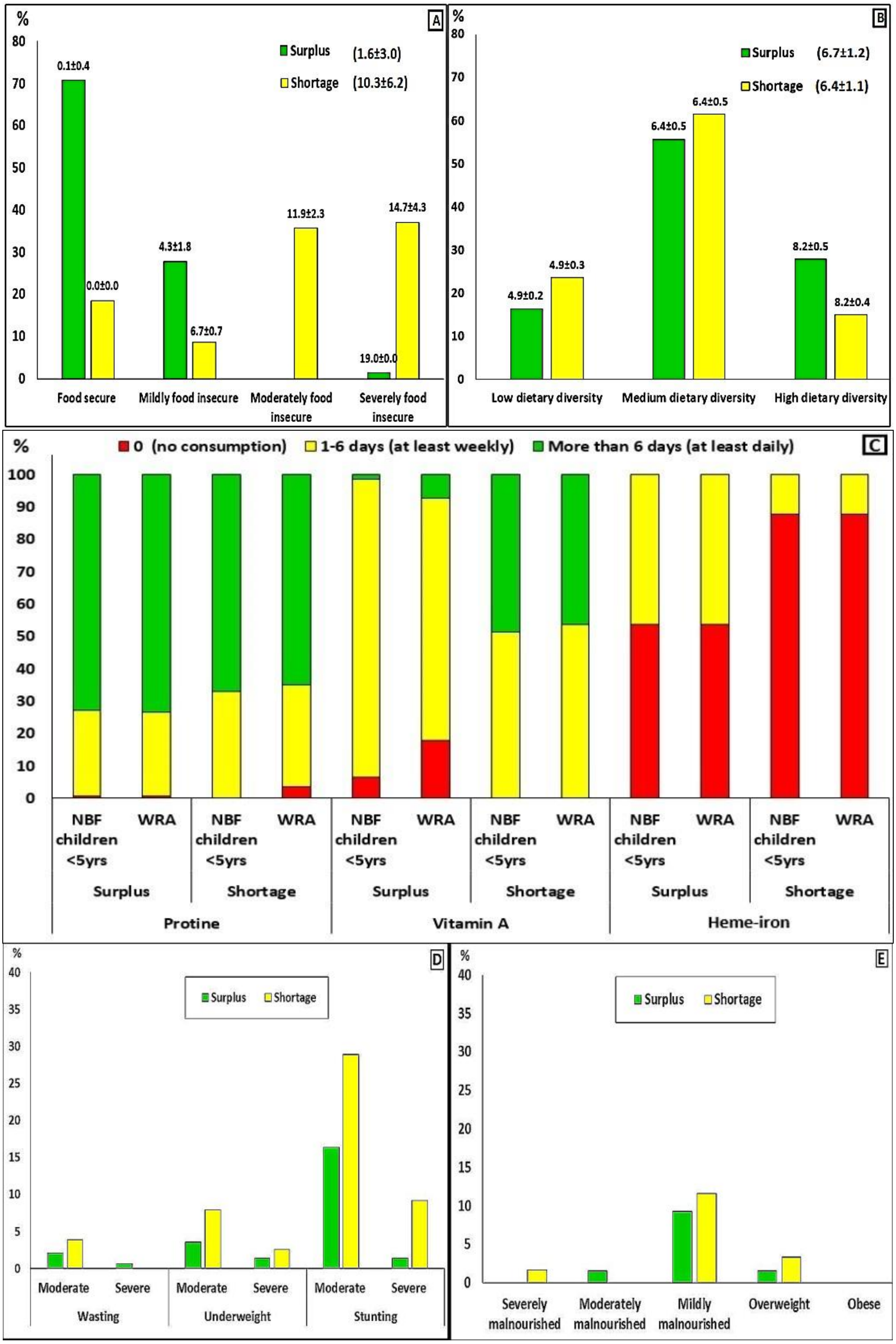

Figure 3: Household Food (In) Security Status, Dietary Intake and Nutritional Status in Yayu: 3A. Proportion of Food (In) Secure Households Based on HFIAS (Mean±SD). 3B. Households Dietary Diversity Based on HDDS (Mean±SD). 3C. Weekly Consumption Trends of Food Groups Rich in Three Key Nutrients. 3D. Nutritional Status of Non-Breast Fed Children between Twelve and Fifty-Nine Months. 3E. Nutritional Status of Women of Reproductive Age.

Source: Jemal 2018

Evaluation of Household Nutritional Status

The mean HFIAS values in Yayu were 1.6±3.0 and 10.3±6.2 for the surplus and shortage season, respectively, revealing that 71 percent of households were food secure during the surplus season and 19 percent during the shortage season (Figure 3A). Concerning the access of the households to a diversity of foods for consumption, the average HDDS was 6.7±1.2 (surplus season) and 6.4±1.1 (shortage season) foods per day. Values show that the majority of the households were in the medium dietary diversity category, both in the surplus and the shortage season, and about 16 percent had a low dietary diversity or dietary energy access in the surplus season (Figure 3B).

The trends in the weekly food consumption of protein, iron, and vitamin A show that the lack of intake of food rich in vitamin A was high in the surplus season: 33.6 percent for non-breastfed children aged twelve to fifty-nine months and 45.7 percent for women of reproductive age. In addition, 80 percent of the children and 96.4 percent of these women did not consume iron-rich food every day during the shortage season (Figure 3C). This indicates a possible nutrient deficiency specifically related to iron. Finally, the anthropometric assessment for the two target groups confirmed the existence of food insecurity in some households: 2.9 percent and 3.9 percent of children were wasted, 5 percent and 10 percent were underweight, and 17 percent and 38 percent were stunted in the surplus and shortage seasons, respectively. (Figure 3D). Also, 13.2 percent and 19.3 percent of the women of reproductive age were underweight in surplus and shortage periods, respectively (Figure 3E).

Nutritional Value of Potentially Edible Species

Of twenty-five potentially edible species, twelve promising species were available during the shortage season and therefore analysed for their nutritional content (Table 1). The results were compared against common shortage and surplus seasons food crops of Yayu (Figure 4A-D).

Table 1: Nutritional Value of Twelve Potentially Edible Species in Yayu (100g Dry—Fresh for Vitamins—Edible Portion)

Species	**Common Name**	**Growth Habit**	**Food Group (*)**	**Energy (kcal)**	**Crude Protein (g)**	**Iron (mg)**	**β-carotene (Provit.-A) (mg)**
Amranthus graecizans	Short-tepalled pigweed	Herb	Green leafy vegetable	142.0±0.5	18.0±1.0	91.3±0.8	0.9±0.1
Carissa spinarum	Bush plum	Shrub	Fruit	252.3±16.5	4.1±0.3	4.0± 0.5	0.1±0.0
Dioscorea alata	Purple yam	Herb	Root/tuber	175.8±3.7	8.46±0.9	12.8±0.0	0.5±0.1
Dioscorea cayenensis	Guinea yam	Herb	Root/tuber	183.0±14.6	7.6±1.2	46.8±0.8	0.2±0.0
Dioscorea prehensils	Yam	Herb	Root/tuber	153.0±16.3	7.3±1.5	12.8±2.3	0.1±0.0
Ficus sycomorus	Sycamore fig	Tree	Fruit	147.9±17.5	6.0±0.2	14.7±0.7	0.2±0.0
Hypolepis sparsisora	False bracken	Fern	Green leafy vegetable	143.0±5.9	18.4±0.9	28.3±0.4	0.2±0.0
Portulaca oleracea	Hogweed	Herb	Green leafy vegetable	97.2±1.5	15.6±0.7	44.5±8.3	0.4±0.0
Rubus apetalus	Raspberry	Shrub	Fruit	151.2±3.9	7.3±0.6	18.5±1.1	1.9±0.2
Solanum nigrum	Black nightshade	Herb	Green leafy vegetable	106.1±11.6	19.3±0.3	24.1±3.0	0.8±0.6
Syzygium guineense	Water berry	Tree	Fruit	244.5±16.5	9.8±0.7	24.9±3.0	0.1±0.3
Tristemma mauritianum	Tristemma	Shrub	Fruit	196.0±19.5	4.7±0.9	24.9±2.3	0.2±0.0

(*) Raw/Unprocessed Food *Source: Aragaw 2017*

Moreover, the energy content of the promising species ranges from 97.20 to 252.30 kcal per dry 100g edible portion (EP), which is relatively lower compared to that of *Zea mays*, *Sorghum bicolor*, and *Eragrostis tef* commonly cultivated in the surplus season. However, *Carissa spinarum* and *Syzygium guineense* generate more energy than other common shortage season crops such as *Ensete ventricosum*, *Solanum tuberosum*, and *Brassica carinata*, which confirms their potential to supplement the energy supply of the smallholders in the shortage season (Figure 4A). The crude protein content of the promising species varied from 4.1g to 19.3g per 100g dry EP (Table 1), and the top three protein-rich species have slightly lower protein contents than most common sources of protein, namely *Vicia faba*, *Pisum sativum*, and *Lathyrus sativus*, but higher than those of the common surplus and shortage season food crops of the area (Figure 4B). The iron content of the promising species ranges between 4.0mg and 91.3mg per 100g dry EP (Table 1). The top three have higher iron contents than all of the common crop species in both seasons, except *Eragrostis tef* (Figure 4C). Concerning vitamin-A contents, *Rubus apetalus* was the species with highest β-carotene content, exceeding that of the top three vitamin-A-rich edible species, but below that of *Brassica carinata*, a commonly consumed shortage season food (Figure 4D).

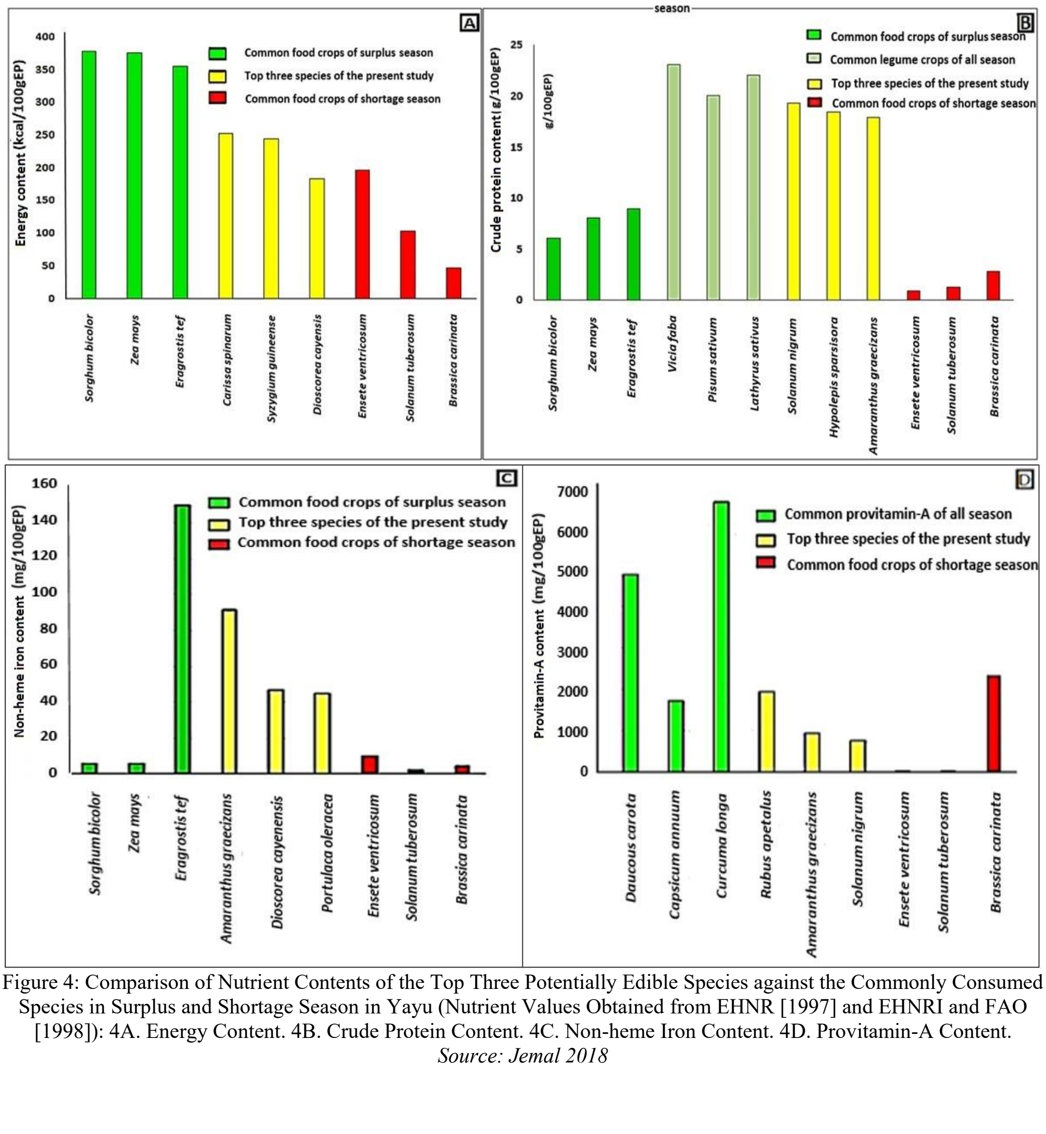

Figure 4: Comparison of Nutrient Contents of the Top Three Potentially Edible Species against the Commonly Consumed Species in Surplus and Shortage Season in Yayu (Nutrient Values Obtained from EHNR [1997] and EHNRI and FAO [1998]): 4A. Energy Content. 4B. Crude Protein Content. 4C. Non-heme Iron Content. 4D. Provitamin-A Content.
Source: Jemal 2018

Discussion and Conclusions

The three forms of agroforestry practices identified in the Yayu area contribute substantially to the four pillars of the food and nutrition security of smallholders in a different but synchronized manner. The practice "multipurpose trees on farmlands" is mostly allotted to the production of the staple crops such as maize and sorghum, but the different multipurpose trees are providers of various products and services. The "multi-storey coffee systems" mainly generate cash through coffee production, while by-products such as fodder, non-timber forest products, and fuelwood are also produced. "Homegardens" mainly supplement the food and cash produced in the other two agroforestry practices by providing species harvestable in different seasons. These findings agree with previous studies in the Jimma zone in southwestern Ethiopia, e.g., Kebebew and Urgessa (2011).

The identified plant species in the assessed AFPs were diverse in purpose, growth habit, and harvesting time, which provides the farmers in Yayu with access to a wide variety of agricultural products and by-products across the year. Regarding the floristic composition and species use, the results of this study agree with the findings in studies conducted by Senbeta et al. (2013) and Etissa et al. (2016) in Yayu in different land-use systems. Besides the generic floristic composition, we detected an untapped potential in other underutilized edible species that could contribute to the food and nutrition security of the smallholder farmers.

Assessing the current food and nutritional status of the Yayu smallholders, besides telling us about the weaknesses in the people's nutrition, they help us to scout the potential of agroforestry practices to address food and nutrition security in the area. The mean Household Food Insecurity Access Scale (HFIAS) of Yayu in the surplus season was lower than in similar areas such as Sidama and Gurage in southern Ethiopia (Joray et al. 2011; Gebreyesus et al. 2015). However, it was higher in those two zones during the shortage time. This might be due to the stronger dependency of Yayu communities on purchased food than on self-produced food, particularly during the shortage season when both food and cash are scarce.

Besides the seasonal shortage, this study detected a potential hidden hunger in the area. The weekly consumption trends show a lack of iron evidenced by the results of the analysis of the nutritional status of small children that showed moderate stunting in both seasons. Nonetheless, the prevalence of stunting in Yayu is still lower than the national average (9.9%) and lower than in other food secure areas, e.g., 14.8 percent in West Gojam (Teshome et al. 2009; CSA and ICF International 2016). Similarly, the prevalence of malnutrition in women of reproductive age in Yayu (8.6% to 13.6% in shortage and surplus seasons) was lower than the national average (27.0%) (CSA and ICF International 2016).

Some of the species growing in the AFPs identified in the present study may have the potential to lessen food insecurity and hidden hunger in both the surplus and shortage seasons. For instance, *Amaranthus graecizans*, *Dioscorea cayenensis*, and *Portulaca oleracea* are rich in iron, *Rubus apetalus* and *Amaranthus graecizans* are rich in provitamin A, and others, such as *Carissa spinarum* and *Syzygium guineense*, also have a high caloric content. It is recommended to further investigate these species with regard to their seasonality and availability, as well as their cultivation, harvesting, post-harvest processing, and utilization.

When contrasted against the FAO suggested policy avenues to tackle food and nutrition insecurity—i.e., (i) facilitating access to foods and nutrients, (ii) making available food rich in important micronutrients, (iii) improving sanitation and health conditions, and (iv) increasing consumer purchasing power—our study appears to address the first two directly by identifying the production systems and species that may provide the required nutrient-rich foods. However, the latter two are only tackled marginally. Health and sanitation depend on institutional and infrastructural conditions reliant on higher political instances and overall the financial support from these. Similarly, householder purchasing power results from the economic dynamics of the region, also determined beyond farmer leverage level; nevertheless, in the case of Yayu, the production of coffee may offer cyclical assurance.

The results of this transdisciplinary study, which included farming system analysis, food and nutritional security assessment, and biochemical analyses with local farmer and stakeholder participation, offer frank alternatives to address locals' nutritional demands. However, we believe that carrying out punctual studies/activities in the following subjects would sustain the uptake of our findings on the identified underutilized species: (i) organization for production and selling; (ii) product exposure, for instance, cooking shows or production of cooking recipes; (iii) behavioral studies on people's consumption habits; and (iv) analyze the legal and sanitary regulations for products introduction.

Finally, in reference to the methodical approach, although labour intensive, this study shows that a systematic, target-oriented effort can achieve comprehensive results in the short term, and eventually serve as a blueprint for similar efforts.

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ABOUT THE AUTHORS

Daniel Callo-Concha: Researcher, Department of Ecology and Natural Resources Management, Center for Development Research (ZEF), University of Bonn, Bonn, Germany

Omarsherif M. Jemal: Researcher, Ethiopian Biodiversity Institute, Addis Ababa, Ethiopia

Habtamu Seyoum Aragaw: Researcher, Ethiopian Institute of Agricultural Research, Jimma Agricultural Research Centre, Jimma, Oromia, Ethiopia

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