Food, agrobiodiversity and diet: the nutritional ethnobiology of the Minangkabau and Mandailing indigenous food systems in West Sumatra

Doctoral Thesis by Lukáš Pawera

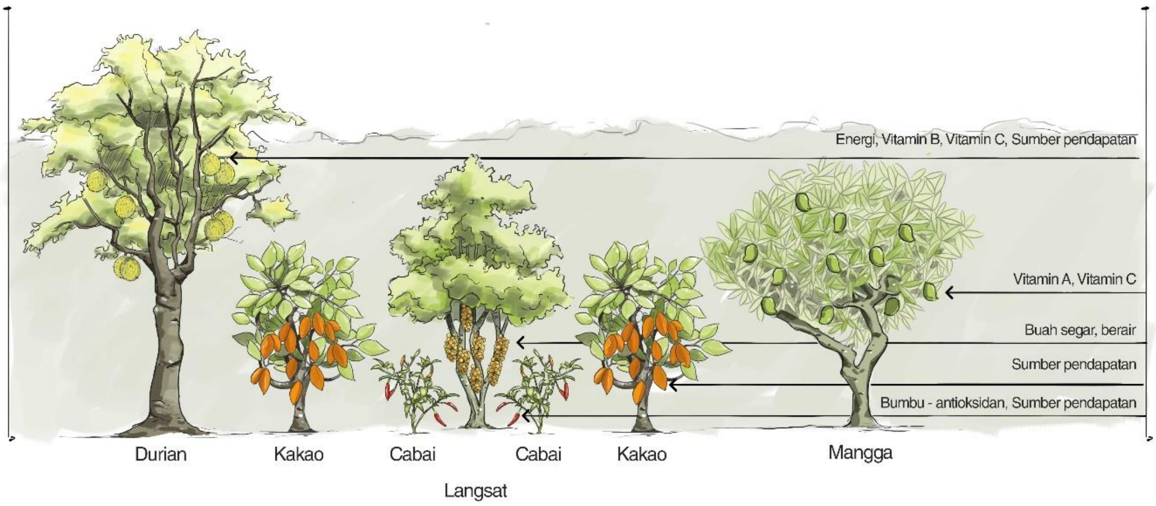
CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Tropical AgriSciences

Department of Crop Sciences and Agroforestry

Czech University of Life Sciences Prague

Food, agrobiodiversity and diet: the nutritional ethnobiology of the Minangkabau and Mandailing indigenous food systems in West Sumatra



DOCTORAL THESIS

Author: Ing. Lukáš Pawera

Supervisor: doc. Ing. Zbyněk Polesný, Ph.D.

Co-supervisors: Dr. Danny Hunter, and Prof. Ali Khomsan, Ph.D.

Prague 2021

A declaration

"I hereby declare that I have done this thesis entitled "Food, agrobiodiversity and diet: the nutritional ethnobiology of the Minangkabau and Mandailing indigenous food systems in West Sumatra" independently, all texts in this thesis are original, and all the sources have been quoted and acknowledged by means of complete references and according to the Citation rules of the Faculty of Tropical AgriSciences."

In Prague, March 2021

....

Ing. Lukáš Pawera

Acknowledgement

I would like to express my sincere thanks to the principal supervisor doc. Ing. Zbyněk Polesný, Ph.D., for his patience and guidance during my doctorate studies. During the doctoral study, flexibility and trust have allowed me to strengthen my research and expertise through interactions with international experts. In my case, this personal network and the journey itself proved to be the key to future growth. Many thanks go to Dr. Danny Hunter, Senior Scientist at Bioversity International, who enabled me to do an internship at Bioversity International in Rome in 2017, where I developed the full proposal for this doctoral project. I express my gratitude to Danny for continuous mentoring. This study established a great collaboration with Bogor Agricultural University (IPB University), and my big thanks go to Prof. Ali Khomsan, Ph.D. from the Department of Community Nutrition for excellent communication and collaboration. Further thanks go to Prof. Ervizal AM Zuhud from the Department of Forest Resources Conservation and Ecotourism of IPB University, for numerous discussions and suggestions. Next, I would like to thank Dr. Amy Ickowitz from CIFOR in Bogor. Amy provided several suggestions and enabled me to visit CIFOR headquarters, where valuable friendships also emerged. I want to thank also Céline Termote, Ph.D. from Bioversity International, who has advised me with challenges related to dietary assessment methods. As conducting the study in West Sumatra, we established cooperation with Andalas University in Padang. For this I thank Prof. Nur Indrawaty Lipoeto from the Department of Nutrition. Also, Swisscontact Indonesia is greatly acknowledged for technical support by the field staff in the study area and by experts in Jakarta's headquarters. The assistance of four data enumerators, graduates of the nutrition program from Andalas University, is also acknowledged. We also thank Ibu Nurainas and Rayfiqa Maulidah from the herbarium of Andalas University for help with the identification of plant specimens. Before the study could start, we appreciate the Indonesian Ministry of Research and Education (KEMENRISTEK) for granting the research permits. We thank the local communities who shared their knowledge and devoted their time to the study. Special thanks go to the key farmers who helped us during the study and were crucial for reaching the randomly selected respondents. For the funding, we would like to acknowledge much Neys-Van Hoogstraten Foundation (NHF) from the Netherlands for supporting this study (Project IN305), without which the study would hardly be possible. Co-funding of the principal investigator's mobility was obtained from the ALFABET mobility under the Erasmus Mundus Action 2 Programme (reference number: 2014-0857/001-001). Funding of publication and additional stipends were received from the Internal Grant Agency (IGA FTZ, Project No. 20205009).

Table of Content

List of tables

List of figures

List of abbreviations

ADB	Asian Development Bank
ASEAN	Association of Southeast Asian Nations
CD	Contribution to Diets (index)
FAD	Food, Agrobiodiversity and Diet (study)
FAO	Foor and Agriculture Organization of the United Nations
HFIAS	Household Food Insecurity Access Scale
IFAD	International Fund for Agricultural Research
MAR	Mean adequacy ratio
MDD-W	Minimum Dietary Diversity for Women
MOH	Ministry of Health of Indonesia
MOFE	Ministry of Environment and Forestry of Indonesia
NAR	Nutrient adequacy ratio
PAR	Platform for Agrobiodiversity Research
PD	Potential for Diets (index)
PPI	Progress out of Poverty Index
PROSEA	Plant Resources of South-East Asia
RAE	Retinol activity equivalent
RDA	Recommended dietary allowance
SDG	Sustainable Development Goal
UD	Underutilization in Diets (index)
UNICEF	United Nations Children's Fund
WFP	World Food Programme
WHO	World Health Organization

Abstract

The overall goal of the present doctoral study was to improve the diet and nutrition of the matrilineal Minangkabau and patrilineal Mandailing rural farming communities in West Sumatra by promoting the more efficient use of agrobiodiversity and local foods. The study objectives were to assess the diets and food security in relation to socio-ecological characteristics, and to document the diversity of food plants and characterise their importance nutritionally and ethnobotanically. The study applied multiple research disciplines and methods from ethnobotany, anthropology, and nutrition. It used a mixed-method approach through which we interviewed 200 individual women at reproductive age and 68 participants during 4 focus group discussions. The data collection included information on socio-economy; food security; food consumption; health basics; attitudes and perceptions; local knowledge; and agrobiodiversity levels and trends in use. The dietary assessment showed that less than half of women reached the minimum dietary diversity (at least 5 consumed food groups). Around two-thirds of women reached recommended dietary allowances (RDA) of macronutrients (energy, protein, fat, carbohydrate), but only a minority reached RDA of micronutrients. The least met RDA were found of folate (reached by 4%), calcium (reached by 9%), vitamin A (reached by 12%), and iron (reached by 16%). Overall, the mean adequacy ratio (MAR) aggregated for 9 nutrients was 0.64, meaning that the diet was adequate by 64%. Tracing the food acquisition pathways revealed that around two-thirds of the consumed nutrients came from markets. However, multiple linear regression showed that the strongest predictor of dietary adequacy was the richness of cultivated food crops. Although there is a transition from obtaining food from natural food environments (cultivated and wild places) to built food environment (local markets), the vast majority of consumed foods were traditional foods. The comparison revealed that despite having slightly higher food insecurity, Mandailing women had better dietary outcomes. The ethnobotanical assessment found that for both ethnics, cocoa agroforestry was a land-use with the highest food plant diversity, and at the same time, cocoa farming was the main source of income. A total of 131 food plant species, corresponding to 167 plant folk foods, were documented. Minangkabau community stewarded a higher diversity of both cultivated and wild food plants than the Mandailing. Both communities perceived local agrobiodiversity positively, but numerous threats and drivers of change have been identified. The main drivers of change were the decreased availability of food plants (mainly due to agricultural intensification) and livelihood and lifestyle changes. On the contrary, the main motivations for continuous use of food plant diversity were that they are obtained for free or at a low cost, and that they are perceived as tasty natural and unpolluted foods. Comparing two societies with different culture and kinship showed that customary governance and matrilineal descent appear to contribute to the conservation of food plant diversity but not to dietary outcomes which are determined rather by ethnic food habits and characteristics of the food environment. The research phase of the study formed a solid base for the applied intervention, which became evidence-based and addressed the actual dietary needs by sharing knowledge and raising awareness on food biodiversity through multi-stakeholder events and community publications. Overall, the study was perceived well by the communities and governments, and it is expected to have a positive impact on nutrition, health, agrobiodiversity, and agriculture resilience. The study was aligned with the National Development Plan of Indonesia, and it contributed to the goals of Aichi Biodiversity Targets, Convention on Biological Diversity, and Sustainable Development Goal 2.

Key words: nutrition, dietary diversity, traditional foods, food environment, ethnobotany

Abstrak

Tujuan umum proyek disertati adalah untuk memperbaiki konsumsi pangan dan gizi masyarakat matrilineal Minangkabau dan patrilineal Mandailing yang tinggal di perdesaan Sumatra Barat melalui promosi pemanfaatan agrobiodiversitas dan pangan lokal. Tujuannya adalah untuk mengkaji pola makan dan ketahanan pangan dalam kaitannya dengan karakteristik sosio-ekologis, serta mendokumentasikan keanekaragaman tumbuhan pangan dan mengkarakterisasi kepentingannya secara nutrisi dan etnobotani. Penelitian menggunakan metode pendekatan multi-disiplin mulai dari etnobotani, antropologi, dan gizi. Pendekatan mixed-method dilakukan dengan mewawancarai 200 wanita usia subur dan 68 partisipan untuk pelaksanaan empat focus group discussions (FGD). Data yang dikumpulkan terdiri atas sosio-ekonomi; ketahanan pangan; konsumsi pangan; kesehatan dasar; sikap dan persepsi; pengetahuan lokal; dan tingkat serta kecenderungan pemanfaatan agrobiodiversitas. Hasil pengukuran konsumsi pangan menunjukkan bahwa kurang dari separo wanita yang mencapai minimum dietary diversity (sekurang-kurangnya mengonsumsi lima kelompok pangan). Sekitar dua pertiga wanita mencapai angka kecukupan gizi yang dianjurkan (AKG) gizi makro (energi, protein, lemak, karbohidrat), tetapi hanya sebagian kecil yang bisa memenuhi AKG gizi mikro. Gizi yang paling sedikit terpenuhi adalah folat (4% wanita), kalsium (9% wanita), vitamin A (12% wanita), dan besi (16% wanita). Secara keseluruhan, mean adequacy ratio (MAR) untuk 9 zat gizi adalah 0.64, artinya hanya 64% subjek yang mengonsumsi diet secara cukup. Penelusuran jalur pangan menunjukkan sekitar dua pertiga gizi yang dikonsumsi berasal dari pasar. Namun demikian, analisis multiple regression menunjukkan bahwa prediktor terkuat kecukupan gizi adalah tanaman pangan yang yang bersumber pada budidaya. Meski ada transisi perolehan pangan dari lingkungan alam (budidaya dan tanaman pangan liar) ke sumber pangan yang berasal dari pasar, mayoritas masyarakat tetap mengonsumsi pangan lokal. Uji beda menunjukkan bahwa wanita Mandailing yang mengalami ketidaktahanan pangan jumlahnya sedikit lebih tinggi, namun mereka memiliki asupan gizi yang lebih baik. Pengukuran etnobotani menunjukkan bahwa kedua etnik memanfaatkan agroforestry coklat sebagai sumber diversitas tanaman pangan, dan pada saat yang sama perkebunan coklat juga menjadi sumber pendapatan yang utama. Terdapat 131 spesies tanaman pangan dari 167 tanaman pangan yang berbeda yang berhasil didokumentasikan. Masyarakat Minangkabau memiliki diversitas lebih tinggi untuk tanaman pangan budidaya maupun tanaman pangan liar dibandingkan masyarakat Mandailing. Kedua kelompok masyarakat mempunyai persepsi positip tentang agrobiodiversitas lokal. Faktor pendorongnya adalah semakin berkurangnya ketersediaan tanaman pangan (terutama karena intensifikasi pertanian) dan perubahan gaya hidup. Motivasi untuk terus memanfaatkan diversitas tanaman pangan adalah karena dapat diperoleh secara bebas di alam atau harga yang murah. Selain itu, tanaman pangan tersebut dipersepsikan bersifat alamiah dan bebas polusi. Setelah membandingkan dua komunitas dengan dua budaya dan sistem garis keturunan yang berbeda, hasil studi menunjukan bahwa pemerintahan adat dan garis keturunan matrilenial nampaknya telah berkontribusi pada keberagaman tanaman pangan, namun tidak berkontribusi pada gizi. Pola makan dan gizi lebih tentukan oleh kebiasaan pangan tradisional, dan karakteristik lingkungan pangan. Fase penelitian ini dapat menjadi landasan kuat untuk intervensi terkait pangan dengan cara berbagi pengetahuan dan peningkatan kesadaran tentang biodiversitas pangan melalui even-even dari pemangkukepentingan dan publikasi di masyarakat. Secara keseluruhan, proyek ini mendapatkan persepsi yang baik dari masyarakat dan pemerintah, dan diharapkan akan mempunyai dampak positip terhadap gizi, kesehatan, agrobiodiversitas, dan ketahanan di bidang pertanian. Proyek ini sejalan dengan Rencana Pembangunan Nasional Indonesia dan memberikan kontribusi untuk pencapaian tujuan Aichi Biodiversity Targets, Convention on Biological Diversity, dan Sustainable Development Goal 2.

Kata kunci: gizi, keanekaragaman pangan, pangan tradisional, sistem pangan, etnobotani

Abstrakt

Disertační práce byla zpracována v rámci projektu, jehož záměrem bylo zlepšit úroveň stravy a výživy rodin drobných zemědělců z matrilineálního etnika Minangkabau a patrilineálního etnika Mandailing ve venkovské oblasti západní Sumatry prostřednictvím efektivnějšího využívání agrobiodiverzity a místních potravin. Prvním cílem disertační práce bylo zhodnotit kvalitu stravy a potravinovou bezpečnost ve vztahu k sociálně-ekologickým charakteristikám. Druhým cílem pak bylo zdokumentovat rozmanitost jedlých rostlin a jejich význam z hlediska tradičního využití a lidské výživy. Studie je založena na multidisciplinárním přístupu zahrnujícím několik vědeckých disciplín a kombinujícím metody z oblasti etnobotaniky, antropologie a lidské výživy. Dotazníkové setření bylo provedeno individuálně na vzorku 200 žen v reprodukčním věku a dalších 68 respondentů se zúčastnilo čtyř skupinových diskusí. Sběr dat zahrnoval informace sociálně-ekonomické, potravinovou bezpečnost, stravování, zdravotní stav, vnímání rostlin jako zdrojů potravin, spektrum jedlých rostlin včetně trendů jejich konzumace. Hodnocení stravy ukázalo, že méně než polovina žen konzumovala pestrou stravu (konzumace potravin alespoň v pěti kategoriích z deseti). Přibližně dvě třetiny žen dosáhly doporučených výživových dávek (RDA) pro makronutrienty (energie, bílkoviny, tuky, sacharidy), zatímco pouze menšina dosáhla RDA pro mikronutrienty. Pouze 4% dotazovaných žen dosáhlo RDA pro folát, 9% pro vápník, 12% pro vitamin A a 16% pro železo. Nutriční vyváženost stravy (MAR) agregovaná pro 9 živin byla 0.64, což znamená, že strava žen byla v průměru nutričně vyvážená z 64%. Sledování původu potravin odhalilo, že přibližně dvě třetiny zkonzumovaných živin pocházelo z potravin zakoupených na místních trzích. Mnohonásobná lineární regrese však ukázala, že nejsilnějším indikátorem nutričně bohaté stravy byla rozmanitost pěstovaných jedlých plodin. Ačkoli studie zachytila přechod od získávání potravin z vlastní produkce a sběru na častější nákup potravin na místním trhu, naprostá většina konzumovaných pokrmů byly tradiční a místní potravinové zdroje. Porovnání etnik odhalilo, že i přes mírně nižší potravinovou bezpečnost, ženy z etnika Mandailing měly pestřejší a nutričně bohatší stravu. Etnobotanická část výzkumu zjistila, že agrolesnické systémy vykazují nejvyšší druhovou rozmanitost jedlých rostlin a současně i největší ekonomický význam pro obě etnické skupiny. Celkem bylo zdokumentováno 131 druhů jedlých rostlin, což odpovídá 167 místním typům rostlinných potravin. Komunita Minangkabau udržovala vyšší rozmanitost pěstovaných i planých jedlých rostlin. Ačkoliv obě komunity vnímaly místní agrobiodiverzitu pozitivně, studie identifikovala četné důvody a faktory přispívající ke snižování rozmanitosti jedlých rostlin. Hlavním faktorem, který vedl k jejich nižšímu využívání, byla snížená dostupnost těchto rostlinných zdrojů (zejména v důsledku intenzifikace zemědělství) a změny životního stylu. Naopak hlavní motivací pro širší využívání místních jedlých rostlin bylo, že jsou získávány zdarma či levně a jsou vnímány jako chutné, přírodní a nekontaminované zdroje potravin. Z porovnání dvou etnických skupin s odlišnou kulturou vyplývá, že tradiční komunitní správa zdrojů a matrilineální systém přispívají k zachování rozmanitosti užitkových rostlin, nemají však vliv na stravování a výživu, jež jsou ovlivňovány především stravovacími návyky a dostupností potravin v daném prostředí. Tato disertační práce se prostřednictvím sdílení výsledků formou publikací a workshopů na komunitní úrovni snažila přispět ke zvýšení povědomí o významu rozmanitosti plodin a potravin pro kvalitu výživy a zdraví. Celkově byl tento výzkumný projekt vnímán místními komunitami a vládou velmi pozitivně a předpokládá se, že bude mít širší dopad na výživu, zdraví, agrobiodiverzitu i celkovou stabilitu a odolnost agroekosystémů. Studie vznikla a byla realizována v souladu s národním rozvojovým plánem Indonésie a přispěla k dosahování cílů Aichi Biodiversity Targets, Úmluvy o Biologické Rozmanitosti (CBD) a Cíle Udržitelného Rozvoje (SDG 2).

Klíčová slova: lidská výživa, pestrost stravy, tradiční pokrmy, potravinové zdroje, etnobotanika

1. Introduction

Food is a basic human need and all people should have access and right to adequate and nutritious food and diet. The acquisition of food is pivotal to the development and functioning of human societies and the evolution of their cultures. Differences in the ways and means humans obtain and use foods have a profound effect on nutrition and health, but also on the social organisation, kinship structure, and child-rearing practices to name a few (Pelto et al. 2013). No matter in what particular way humans obtain their food in their environment, the essential and ultimate resource is food biodiversity. From both plant and animal sources, biodiversity of food is a vital source of energy, nutrients, and bioactive compounds that sustain human beings. It may come directly from various agricultural systems, natural environments such as forests, rivers and lakes, or increasingly indirectly from food vendors, restaurants and markets. These interactions happen in the food environment - the consumer interface with the food system that encompasses the availability, affordability, convenience, and desirability of foods (Herforth & Ahmed 2015). Food environments are part of the overall food system, which encompass the entire range of actors and their interlinked activities involved in the production, processing, distribution, consumption and disposal of food products that are produced from agriculture, forestry or fisheries (FAO 2018). One of the most important results of food system processes are nutritional outcomes. However, the current global food system is still failing, as two billion people experience hunger or malnutrition (FAO 2020). World food supplies are getting increasingly homogenised by a few major crops and their products (Khoury et al. 2014). Currently, malnutrition in all its forms, including overweight, obesity, undernutrition, and their coexistence, is the leading cause of death globally and affects every country (Development Initiatives 2018). Moreover, planetary boundaries are being pushed, and nourishing a growing population in ways that support human and planetary health is one of the greatest challenges of the Anthropocene (Downs et al. 2020; Willet et al. 2019).

In Indonesia, almost one-third of children under 5 years are too short for their age (stunted), which puts them at risk of not achieving their full physical and cognitive potential (MOH 2019). Every second pregnant woman suffers from anaemia, while at the same time, there is a growing double burden of malnutrition, where overnutrition is on the rise (UNICEF 2018). Achieving a healthy diet from sustainable food systems is one pressing issue of utmost importance and magnitude in Indonesia (Vermeulen et al. 2019). Indonesia is bio-culturally a mega-diverse country with the 2nd largest cultural diversity in the world, over 14,700 islands, and between 30,000 – 40,000 spermatophyte plant species, accounting for 15.5% of the world's flora (MOEF 2014). Yet, only 19,232 plant species have been identified and named until now (Widyatmoko 2019). Through the interaction with biodiversity, local people have evolved rich gastronomies and diets based on a wide array of local food resources (Vermeulen et al. 2019). The locally cultivated or collected agrobiodiversity is a crucial resource for local people's nutrition and well-being. According to the Plant Resources of South-East Asia (PROSEA)[1], Indonesia has a high biodiversity of useful plants, but many of them are neglected and underutilised, which could contribute more to the diets (Westphal and Jansen 1986).

Considering the rich agrobiodiversity and high malnutrition at the same time, this doctoral study aimed to understand these linkages and leverage the potential of agrobiodiversity in West Sumatra. The study's overall goal was to contribute to food and nutritional security of the matrilineal Minangkabau and patrilineal Mandailing rural farming communities through leveraging the potential of local food biodiversity. Therefore, the study employed a research-for-development approach, which combined a fieldwork phase, followed by scientific data analysis, and a short applied intervention to contribute to desired outcomes and impacts on the ground. The impact in time, however, could not be monitored due to limited time and budget.

The research framework considered a socio-ecological model of food and nutrition, which looked at the main socio-cultural and environmental factors influencing food consumption (Pelto et al. 2013). The first study objective was to assess the diets and food security of the communities in relation to socio-ecological characteristics. The second objective was to document the diversity of food plants and characterise their dietary importance and potential. The specific aims within those objectives are given later in chapter 4. Goal and objectives.

The research framework aimed to answer four key research questions. As dietary adequacy is the key dependent variable in this research, the study aims to identify the predictors of adequate diets (research question 1). Besides determining the predictors, the research aims to quantify how much food and nutrients flows through different acquisition pathways such as from markets or own production and land-use systems (research question 2). The third research question is about answering what the level of food plant diversity is, and what barriers and motivations affect its persistence and use. The last question aims to compare the findings between the ethnic groups and explain how the different cultural system in a similar landscape affects agrobiodiversity and dietary outcomes (research question 4).

[1] PROSEA (Plant Resources of South East Asia: http://proseanet.org/prosea/)

2. Literature review

2.1 Current situation of food systems and nutrition in Indonesia and worldwide

Although the current global food system is believed to be capable of generating enough calories for the human population of the world, still around two billion people experience hunger or malnutrition (FAO 2020). A rapidly increasing number of nations experience the double burden of malnutrition, where undernutrition coexists with overweight, obesity and other diet-related diseases (Development Initiatives 2020). Recent studies have demonstrated that the current food systems are not only failing to deliver healthy diets but are also inequitable and environmentally unsustainable (Béné et al. 2019; Willet et al. 2019). Globally, stunting among children has slightly declined, but there is new evidence that there is a reversal rise of world hunger (FAO, IFAD, UNICEF, WFP and WHO 2018). Therefore, sustainable food systems are needed, which deliver food security and nutrition in a way that the economic, social and environmental bases to generate food security and nutrition for future generations are not compromised (FAO 2018).

Currently, malnutrition is responsible for more illnesses and health problems than any other factor, and the burden of malnutrition across the world remains unacceptably high (Development Initiatives 2018). With changes in globalisation and agricultural industrialisation of rural areas, local foodways and human cultures are changing tremendously. Global trade and markets play an omnipresent role in influencing human lifestyle and dietary habits, and among indigenous and vulnerable communities, tend to increase the consumption of highly processed foods of poor nutrient value (Kuhnlein et al. 2009). Indigenous and local people's health is particularly prone to these rapid shifts from traditional to so-called western diets and lifestyles, resulting in a rapid increase of obesity, cardiovascular disease, and type 2 diabetes, and sometimes with impact on physical, social, and mental well-being (Gracey & King 2009).

Improving diets and ending all forms of hunger and malnutrition by 2030 is one of the most pressing Sustainable Development Goals (SDG 2). When the human diet and nutritional status improve, it helps break the inter-generational cycle of poverty and leads to a myriad of benefits and socio-economic growth of individuals, families, communities, and countries. However, human diets are inextricably linked not only with human health but also with sustainability and planetary health. The EAT-Lancet Commission on Healthy Diets From Sustainable Food Systems demonstrated that the current dietary patterns are pushing the planet beyond its boundaries (Willet et al. 2019). This puts both humanity and nature under threat. The Commission identified the key challenge before us, which is to provide a growing human population with healthy diets from sustainable food systems.

"*Food has the potential to nurture human health and support environmental sustainability. Instead, our food is threatening both. The challenge before us is to provide a growing global population with healthy diets from sustainable food systems.*" (Willet et al. 2019).

The findings from the EAT-Lancet Commission provided the first scientific targets for a healthy diet from sustainable food and agriculture systems that operates within planetary boundaries. To meet this target, dietary changes need to be combined with improved agriculture and reduced food waste. Agriculture will also need to produce a variety of nutrient-rich crops, and the use of land and ocean will have to be better governed (Stockholm Resilience Center 2020).

South-East Asia is experiencing a growing human population and the current food systems are largely unsustainable in the context of both supply and demand of food (Weinberger 2013). The region is also experiencing a rapid dietary transition and a double burden of malnutrition. More than half of the world's stunted children, more than two-thirds of wasted children, and almost half of overweight children are found in South-East Asia (UNICEF 2016).

In Indonesia, from 2016 to 2018, around 22 million of Indonesians (8% of the population) experienced hunger (ADB 2019). In 2019, Indonesia also ranked poor on the global hunger index compared to other ASEAN countries (Global Hunger Index 2020). Out of 107 countries, Indonesia was placed 70th (worse than Malaysia, Thailand, Vietnam, Myanmar and the Philippines). In 2019, the proportion of stunted children under 5 years in the country reduced to 28% from 32% in 2018 (MOH 2019). Anaemia is also widespread with 42% of pregnant women and 28% of all women having anaemia (Development Initiatives 2019). The overall malnutrition level is still high, despite the massive efforts from the government and economic growth in the country (UNICEF 2018). Moreover, Indonesia undergoes a double burden of malnutrition, as it also suffers from growing rates of overweight (UNICEF 2018). The country has also reached the 6th highest number of people who have diabetes globally, and the proportion of mortality caused by non-communicable diseases (NCDs) was 73% in 2016 (Vermeulen et al. 2019). The economic costs of diet-related diseases in Indonesia are estimated to be around USD 248 billion per year (UNICEF 2016).

While ranked as a middle-income country, Indonesian diets remain far more typical of a low-income country with low meat consumption and extreme dependence on a single staple –

rice (Vermeulen et al. 2019). In general, rural and poor Indonesians are vulnerable to deficiencies of proteins and fats, fruits, and vegetables. For example, in Maluku, the wealthiest quintile of the population consumes on average 74 g of protein per day while the poorest quintile consumes 31 g (Vermeulen et al. 2019). The recommended daily allowance of protein for adult Indonesians ranges from 56 g to 65 g, depending on age and gender (MOH 2013). This demonstrates that the poorest ones are often far below the recommended amount, while the wealthiest ones consume protein excessively. Poverty and high food prices remain major challenges in the effort to increase access to nutritious food (Arif et al. 2020). But in bio-culturally diverse Indonesia, food systems and diets vary along with immense geographical, socio-economic, and cultural diversity. With this variation, Indonesia has a multitude of food systems and dietary patterns rather than one 'Indonesian diet' (Vermeulen et al. 2019). According to a recent study by Colozza & Avendano (2019), traditional diets and practices continue to be dominant in both rural and urban areas, despite the context of rapid socio-economic change and urbanisation (Colozza & Avendano 2019). However, some other studies are showing a rising consumption of ultra-processed foods (e.g., instant noodles, sweet bread, fried snacks) in urban contexts such as Jakarta (Setyowati et al. 2018), peri-urban areas in Java (Mayer and Rohmawati 2019) and even in some rural areas (Arif et al. 2020).

In West Sumatra, local communities have a relatively diverse diet, derived mainly from traditional foods (Swisscontact 2016; Lipoeto et al. 2001). However, there is still a high incidence of diet-related problems, such as coronary heart diseases and anaemia (Lipoeto et al. 2004a). The diet quality was found low foremost due to a monotonous diet and high saturated fatty acid intake (Stefani et al. 2018). It has been reported that the Minangkabau people have a high risk of dyslipidemia, which is likely driven mainly by the high intake of dietary fat from poor quality sources (Djuwita et al. 2003). Minangkabau people also have high levels of total cholesterol and low-density lipoprotein cholesterol compared to other ethnicities in Indonesia (Hatma 2011). Moreover, the prevalence of obesity is high among Minangkabau women (Desmawati et al. 2019). Lipoeto et al. (2004b) described the nutrition transition, which has had some positives and some negatives. Their study found that in the period from 1983 to 1999, there was a high increase in consumption of soybean, an overall decrease in energy intakes (kcal), and an increase in the proportion of dietary energy obtained from non-carbohydrates such as protein and fat (Lipoeto et al. 2004b). The study also pointed to a major shift of occupation from agriculture, forestry and fisheries to manufacturing and services. This translated into a significant reduction of physical activity. The nutrition transition is thus reflected by changes in the proportion of food intakes and dramatic shifts in causes of death from infectious to chronic non-communicable diseases at the same time (Lipoeto et al. 2004b).

In Indonesia and broader South-East Asia, the increase in the prevalence of non-communicable and cardiometabolic diseases is also caused by a transition to a more sedentary lifestyle (Angkurawaranon et al. 2014). In this context, extrapolated with intensified mainstreaming of modern lifestyles and global foods, local people tend to decrease consumption of traditional foods, and on the contrary, increase the intake of instant foods, ultra-processed food products and nutritionally poor snacks. In this scenario, public health, social, cultural, and environmental costs are extremely high and have yet to be estimated. In West Sumatra, the Minangkabau people appear to be more resistant to the adoption of western foods and diets, due to their culture and proudness of traditional foods, which slows down the dietary transition to some extent (Lipoeto et al. 2012; Lipoeto et al. 2001).

The causes of inadequate diets and malnutrition in Indonesia are multi-faceted. According to Februhartanty (2005), one of the causes is the low awareness on nutrition due to a lack of mainstreaming nutrition into the education system. A recent review of determinants of child stunting in Indonesia found that it is associated with numerous factors, i.e., premature birth, short birth length, male sex, non-exclusive breastfeeding for the first 6 months, short maternal height, low maternal education, high poverty, having unimproved latrines, using untreated drinking water, poor access to healthcare, and living in rural areas (Beal et al. 2018). Child stunting is also related to food insecurity, and provinces with poor access to food are those with the highest stunting rates (SMERU 2015). Tackling stunting is one of the top priorities for research and development in the country (Beal et al. 2018). There is a call for an investment in research and development of agriculture, food systems and rural infrastructure (ADB 2019). It is also recommended to increase the resilience to climate change and natural shocks which are frequent in the region (ABD 2019). While nutrition and dietary targets have been mainstreamed relatively well into programs, the agricultural policies have been recommended to reorient their focus from rice production to the overall diversification of production and more efforts to increase the production of vegetables and fruits (Arif et al. 2020).

"*The most poverty-stricken communities with high stunting rates in Indonesia do know how and where to fish. What they lack is a fishing rod and access to unpolluted fishing waters.*" (Gounjaria 2020).

Undoubtedly, there is a need to adopt diets that could benefit both human and planetary health in Indonesia (Vermeulen et al. 2019). The authors specified that this should include the substitution of refined rice by a wider variety of starchy staples; increasing intake of fruits and vegetables that have traditionally been grown in Indonesia; increasing consumption of proteins and fats among more undernourished communities; and lastly curbing on added sugars and oils in processed foods. Through its Development Plans, Indonesia is committed to securing good nutrition for all. The emphasis on diet and nutrition is supported by national dietary guidelines (MOH 2014a). More attention has recently been paid not only on nutrition but also to the more holistic food system approaches:

"*Indonesia has an uncommon chance to take a different pathway, a course correction towards healthy diets based on sustainable production. The key to unlocking this sustainable future will be to put into practice a true 'food system approach' to meeting goals for food security, health, agricultural development and the environment.*" (Vermeulen et al. 2019)

2.2 Importance of food biodiversity for diets and nutrition

Despite increasing homogenisation of the major crops that contribute to world food supplies (Khoury et al. 2014), millions of rural households throughout the developing world continue to rely on a diversity of plant and animal species to nourish themselves and to support their livelihoods (Kuhnlein et al. 2009). Food biodiversity is the core of indigenous peoples' food systems. However, many barriers hinder the utilisation of this biodiversity despite its nutritional potential (Hunter & Fanzo 2013). The neglection of food biodiversity, resulting in poor diets, is coming at high costs to national healthcare budgets, economies, and societies at large.

Local farmers and traditional communities are going through a transitional period while experiencing a loss of biodiversity, traditional knowledge, and cultural values, which results in a dilution of a true sense of community (Pieroni et al. 2016). Indigenous communities are in transitions, where they are losing their traditional knowledge, which had previously enabled them to source local food biodiversity, while having limited access to education and nutritional knowledge. Some studies are showing that the persistence of ethnobotanical knowledge is associated with the health of indigenous peoples (McDade et al. 2007). A recent review suggested that agrobiodiversity has a consistent association with more diverse diets (Jones 2017). Kennedy et al. (2017) emphasised that the diversity of both cultivated and wild plants, and animals used for food, is a critical element for tackling malnutrition and ensuring sustainable food systems. Currently, there is a growing interest, recognition and new approaches for using wild food plants for food and nutritional security (Borelli et al. 2020). This food biodiversity-based approach is a holistic, rather than a specific, vehicle for diversifying diets and supplying vital nutrients (Kennedy et al. 2017; Hunter & Fanzo 2013). Mutual linking of biodiversity with nutrition builds a common path leading to a reinforcement of nutrition security and sustainability (Toledo and Burlingame, 2006). Yet, crop and food biodiversity have been missing in many strategies and programs aiming to improve nutrition (Kennedy et al. 2017; Hunter & Fanzo 2013; Fanzo et al. 2011; Niehof 2010).

In rural parts of bio-culturally rich countries such as Indonesia, the locally cultivated or collected agrobiodiversity is still crucial for many local people's diet and livelihood. According to PROSEA, which mapped many of the region's useful plants, a high proportion of the plant biodiversity is used for food (Westphal & Jansen 1986). The authors mentioned that there are numerous crops and lesser-known species that could contribute to a balanced diet, if not overlooked. Many local species are, in fact, neglected and underutilised plants with high nutritional content (Hunter et al. 2019; Powell et al. 2015; Grivetti & Ogle 2000). This offers a certain potential for alleviating micronutrient deficiencies in some contexts, such as among rural and traditional communities (Powell et al. 2015). Traditional and wild foods plants also represent bioactive functional foods that could contribute to health and immunity to various illnesses (Pieroni & Price 2006; Heinrich et al. 2016).

Ancestral and contemporary traditional diets are known to offer valuable health benefits (Crittenden & Schnorr 2017). There are also suggestions that humans and their genome are adapted to the foods, diets and environments from past times and that contemporary diets and lifestyles are not optimal for the human genome (Cordain et al. 2005). The western dietary pattern is characterised by high consumption of ultra-processed foods, which also push the human gut microbiome to produce negative health outcomes and inflammation (Zinöcker & Lindseth 2018). Among indigenous communities, higher use of wild foods has also been linked with greater food security (Smith et al. 2019). To access wild foods, it is crucial to maintain traditional food knowledge, which represents an integral part of local and sovereign food systems (Aziz et al. 2020).

Despite the rich agrobiodiversity and food cultures in Indonesia, the use of food resources is far from optimised as demonstrated by monotonous diets and poor nutritional status of the Indonesians. According to Niehof (2010), one of the main reasons for this is a struggle to be food secure, and thus spending much time and labour on account of producing the most important Asian food crop – rice (Niehof 2010). In West Sumatra, the strong preference for rice caused a major neglection of other staple crops (David et al. 2013; Rudito et al. 2002).

Agrobiodiversity in Indonesia is also increasingly facing the pressure of economic growth and policies that drive the commercialisation of farm and livelihood systems. It becomes more challenging to maintain agrobiodiversity-rich lands such as homegardens (Abdoellah et al. 2020). Yet, the study of Ickowitz et al. (2016) indicated that people living inside or close to forests in Indonesia consume more micronutrient-rich foods than those not living in the forest proximity. A recent study with rural households from over Indonesia found a trend of decreasing agrobiodiversity and declining dietary diversity despite increasing incomes and market access (Mehraban & Ickowitz 2021). Other research has shown that local foods provided as school lunches can significantly improve the nutritional intake and health status of the schoolchildren (Sekiyama et al. 2017).

The present study believes that it is essential to foster research and development trajectories, which are exploring the nutritional and cultural values of traditional food diversity, while explaining and addressing the reasons for the decline in the use of local foods. To better understand the food consumption, which determines the nutrients consumed, it is necessary to go beyond a solely nutritional approach and combine social and cultural approaches (Gartaula et al. 2018; Pelto et al. 2013). Historically, dietary interventions have focused primarily on protein and calories, later on minerals and vitamins, and most recently on functional and healthful properties of foods, such as antioxidants. In each of these cases, a reductionist focus on a single compound or nutrient has often neglected the foods, diets, and socio-ecological contexts of food systems. To better understand and leverage the potential of agrobiodiversity for nutrition, the present research will apply ethnobiological and nutritional approaches.

2.3 Indigenous food systems in the context of global socio-ecological change

Around 470 million indigenous people spread over 90 countries rely on their indigenous food systems where food is primarily grown and harvested from natural food environments (Kuhnlein et al. 2013). The indigenous peoples' knowledge co-evolved with the traditional way of life in local ecosystems. Since indigenous peoples have survived in particular ecosystems for thousands of years, their food systems can be considered sustainable, although they are also changing and evolving (Kuhnlein 2015). Indigenous peoples, whose lands occupy over a quarter of the world land, are recognised as the custodians of 80 % of the world's biodiversity, as their territories coincide with the most biodiverse areas on the planet (Garnett et al. 2018). Their health and well-being are inextricably linked to local biodiversity and the environment. For many indigenous communities, farming, hunting and gathering activities are principal for their health and well-being (Kuhnlein & Receveur 1996).

Compared to mainstream food systems, indigenous food systems tend to more biodiverse and also have a cultural-spiritual dimension (Kuhnlein et al. 2009). They are known to be rich in food biodiversity, combining both edible animal and plant species from across the landscape (Powell et al. 2015). Locally available food species numbers vary depending on the ecosystem. The highest number of edible species are found to be used by the communities living in tropical and biodiverse environments. The FAO-CINE program on indigenous food systems (Kuhnlein et al. 2009), found the highest number of edible species and their varieties used by Karen people in Thailand (387), Pohnpei in Micronesia (381), and Dalit in India (329). On the contrary, the lower food biodiversity richness was found in more cold or arid environments such among Maasai in Kenya (35), or Gwich'in in the northern territories of Canada (50). What foods are available from which the individual can choose is dependent on the environment and is further moderated by culture, economy, technology and politics. The dietary transition and extent of use of local and imported foods vary across the communities. Igbo people in Nigeria were found to have the highest share of dietary energy from local foods (96%), followed by Awajun people in Peru (93%) and Karen people in Thailand (85%). On the contrary, the Maasai, Pohnpei, Ingano, Bhil and Dalit had the majority of their dietary energy derived from refined and imported foods (Kuhnlein et al. 2009). A review by Penafiel et al. (2011) confirmed that local foods were found to be an important source of energy, micronutrients, and diverse diets of rural communities living in highly biodiverse ecosystems.

The traditional food systems which are changing with the complexities of social and economic circumstances are becoming increasingly affected by the forces of globalisation even in remote areas. Despite the wealth of knowledge indigenous peoples have of their local environment and food systems, they often face vulnerabilities derived from extreme poverty, discrimination and marginalisation. This can mean that access to their land and resources becomes limited, causing adverse health outcomes (Kuhnlein et al. 2015). Global trade and markets play an omnipresent role in influencing human dietary and lifestyle habits, and among indigenous communities, tend to increase the consumption of highly processed foods of low nutrient value (Kuhnlein et al. 2009). Diets have become more energy-dense and higher in fats, sugars and salt, for example, in soft drinks, snack foods and ready-to-eat convenience foods (Kuhnlein & Receveur 1996). Local food systems are increasingly composed of a mixture of local foods and processed foods purchased from markets, bringing changes not only to diets and health but also changing values and transforming landscapes. Rapid dietary changes of indigenous peoples are posing threats also to the traditional knowledge required for traditional food system maintenance (Kuhnlein & Receveur 1996).

Currently, numerous drivers are accelerating the decline in biodiversity and use of indigenous foods. Some of the main drivers are changes in land-use, climate change, agriculture intensification, overharvesting, socio-economic change, expansion of markets and the loss of local knowledge (FAO 2019; Bharucha & Pretty 2010). These factors drive the homogenisation of local foodways, which may contribute to malnutrition and overconsumption, resulting in the nutrition transition and epidemic of obesity and chronic diseases (Kuhnlein 2015). The evidence base of the nutrition and health status of indigenous peoples worldwide needs to be strengthened. The challenge is that many middle- and low-income nations do not yet collect or segregate the nutrition and health data by ethnic group (Kuhnlein 2009). Ultimately, more research and investment into indigenous agrobiodiversity and food systems could help to tackle the nutritional challenges while maintaining bio-cultural diversity.

Since food system lens and approaches are more recent phenomena, comprehensive food system studies from Indonesia are virtually non-existent. However, there are various studies related to one or two components of the food systems. Many studies have traditionally looked separately at agriculture, forestry and land uses, biodiversity and local knowledge, or food and nutrition. Only very few studies considered linkages or trade-offs among different food system components and outcomes. Pioneering work with more holistic food system approach was done on socio-cultural aspects of nutrition and food system of Baduy people in Java who maintain unique knowledge and cultural systems (Khomsan et al. 2012). Dounias et al. (2007) studied more systematically the diets and nutritional status of former hunter-gatherers in Borneo with relation to the level of their remoteness. They found that more remote communities had more diverse diet and better nutritional status and physical fitness. Currently, there are ongoing but unpublished studies on indigenous food systems of Tenger people in Java, Dayak people in Borneo, and Orang Rimba in Sumatra. In West Sumatra, a study by David et al. (2013) highlighted the linkages of agrobiodiversity and diets with traditional knowledge of matrilineal Minangkabau women. Yet, none of these studies from Indonesia compared diets and food systems between societies adhering to matrilineal and patrilineal kinship and descent. There is a study from North-East India, which compared food systems of matrilineal Khasi and patrilineal Chakhesang tribes and found that women in both societies play equally important roles in agrobiodiversity management, subsistence agriculture, and household food provisioning (Elena & Nongkynrih 2017). According to the authors, different cultural rules shaped gender relations, women's status, and appreciation of women's work. Gender roles were more flexible among the matrilineal Khasi.

Currently, it is momentous that international institutions such as the Food and Agriculture Organization of the United Nations and their partners are coming forward to strengthen collaboration and research on indigenous food systems. On 28 September 2020, a new Global Hub on Indigenous Food Systems has been launched[2].

2.4 Nutrition-sensitive agriculture and its impact on nutrition outcomes

An increasing number of governments, donors, and research or development organisations are committed to supporting nutrition-sensitive agriculture to contribute to achieving national and global development goals (Ruel et al. 2018). Policy, programme or project intervention can be considered nutrition-sensitive if it contributes to better nutrition by addressing some of its underlying determinants such as access to safe and nutritious foods, adequate care, and a hygienic environment (FAO 2016). Nutrition-sensitive agriculture is relatively a recent concept that aims to address the dietary needs by agriculture, new knowledge and available food resources. Foremost, it explicitly incorporates nutrition objectives into agriculture programmes to improve food and nutrition security, but also health, education, economic, environmental and social aspects (Jaenicke & Virchow 2013).

Nutrition-sensitive agriculture can have several pathways that lead to improved nutrition (Herforth & Harris 2014). The key pathways are through households own production and consumption; increased household income (through increased production or supporting policies or schemes) enabling increased purchases of food and health care; adjustment of women's workload resulting in improving child care or maternal nutritional status; and improved women's empowerment to control the allocation of resources for food, health and care (Berti et al. 2016). A recently added pathway is the effect of policies on food prices and consumption (Gillespie et al. 2019). However, the various pathways do not operate in isolation but interact with synergies or trade-offs (Gillespie et al. 2019). The impacts of the different pathways are still unclear as the amount of supporting evidence for each pathway is scattered and limited. The available reviews conclude that more research is needed to better understand the relationship between agriculture and nutrition, and to design the interventions with a high probability of having positive nutrition and health outcomes (Berti et al. 2016).

A systematic review of evidence from South Asia (Pandey et al. 2016) found that interventions such as homegardens, livestock rearing, poultry and aquaculture may improve

---

[2] Through a collaboration with the Indigenous Partnership for Agrobiodiversity and Food Sovereignty, the Ph.D. candidate is a core member and expert in the new Global Hub.

production diversity and women's empowerment, which then translate into intermediate nutritional outcomes such as consumption of nutrient-rich crops and dietary diversity. However, there is no evidence for improving final nutritional outcomes, such as child growth or health. A similar conclusion came from a more recent review by Bird et al. (2019) where the evidence of impact on final nutrition outcomes was also limited and mixed. However, the evidence has further increased for the improvement of intermediate outcomes such as dietary diversity and increased consumption of nutrient-dense foods. Similar takeaways came out from a global review by Ruel et al. (2018) which consolidated the evidence from impact evaluations that nutrition-sensitive agriculture improve a variety of nutrition outcomes in both mothers and children, especially when these interventions included nutrition behaviour change strategy and women empowerment.

There is an ongoing discussion on the importance and trade-offs between market approaches and farm production diversity. First, the marketing and selling pathway need to be better monitored because of its dual role of providing cash to the producers who can use it to purchase nutritious foods but also nutritionally poor foods. Undoubtedly, markets may diversify the diets (Sibhatu & Qaim 2018), but they may also contribute to the escalation of non-communicable diseases through the consumption of unhealthy and ultra-processed foods (Moubarac et al. 2017; Demmler et al. 2017). Also, the affordability of foods is an important determinant of nutrition (Jaenicke & Virchow 2013). And nutrient-rich foods such as fruits and vegetables are rather expensive for many, especially the poor ones. A recent SOFI report (FAO 2020) demonstrated that 50% of the world population cannot afford a healthy diet. In Indonesia, a modelling study showed that a nutritious diet for an average household costs 1,191,883 IDR (81 USD) per month and that around 38% of households in the country cannot afford it (WFP 2017).

While some studies are showing that more market-oriented farms have more diverse diets (Sibhatu & Qaim 2018), the others are showing that production diversity is more strongly associated with dietary diversity than agricultural income (Jones 2017). More diversified agriculture, which includes a variety of food crops as well as poultry or livestock are capable of providing the means for a balanced diet (Kennedy et al. 2017). Moreover, agrobiodiversity may not only provide food and nutrients, but it also provides ecosystem services and serves as a buffer to climate change and other biotic and abiotic stresses (Meldrum et al. 2018). Agriculture intensification and adoption of monocultures lead to a decreased level of agrobiodiversity, higher risks and external input use, and reduce social equity and sustainability in Indonesia (Abdoellah et al. 2020; Abdoellah et al. 2006).

In South-East Asia, the current food systems are largely unsustainable and there is a need for nutrition-sensitive food systems (Weinberger 2013). According to the author, home and community gardens could play a more important role in food systems of the region. By increasing the availability, affordability and consumption of nutrient-dense foods, such as fruits, vegetables and pulses, malnutrition could be decreased. Agriculture and food system approaches also have a role to play for enhancing social, economic and sustainability goals (Weinberger 2013).

In Indonesia, nutrition-sensitive agriculture approaches are mostly missing. There are a few older studies focusing mainly on the potential of homegardens for nutrition (Abdoeallah & Marten 1986; Marten & Abdoellah 1987; David et al. 2013). In West Java, a study on the linkages of agricultural systems and nutrition found that nutrient deficiencies are mainly a consequence of insufficient land and a heavily rice-based diet despite high crop diversity (Abdoeallah & Marten 1986). Crop diversity was found to be significant in order to produce calcium, iron, riboflavin, but it did not provide enough of other nutrients such as vitamin A and calcium. The study of David et al. (2013) from West Sumatra highlighted the nutritional importance of homegardens, and the linkages of local biodiversity with the matriarchal cultural system where women inherit the land, carry traditional food knowledge and convert biodiversity into nutritious meals for the family.

As studies have shown, nutrition-sensitive agriculture and food systems offer an interesting potential to improve nutrition, but its implementation requires specific capacities at multiple levels of the intervention programs. Worldwide, nutrition has traditionally been hosted in institutions and ministries of health rather than within agriculture, food or other sectors (Aryeetey & Covic 2020). According to the authors, a key leverage point that is critical for operationalising nutrition-sensitive agriculture and food systems is to foster multi-stakeholder collaboration between the agriculture and food, health or nutrition sectors. In their review, Ruel and colleagues (2018) concluded that nutrition-sensitive agriculture should focus on improving diets rather than solving more complex problems such as stunting. They also called for expanding the approach towards sustainability and cost-effectiveness, and urge for bringing more evidence, actions and successful examples of agriculture improving nutrition.

2.5 Pathway from biodiversity to nutrition – A conceptual model

Food biodiversity, both plant and animals, is an essential source of energy, macronutrients, micronutrients and bioactive compounds for human beings. It comes from a vast biological diversity of wild or domesticated plants and animals. These food sources are derived from different agricultural lands (cultivated food environments) and from forests, fallows, rivers, lakes (wild food environments), and increasingly from formal or informal markets (build food environments). Local communities obtain their food biodiversity from a complex and likely transitioning food environment (Downs et al. 2020).

While the positive relationship between biodiversity, diets and health seem clear, there is limited scientific evidence quantifying the relationships and pathways (Kennedy et al. 2017; Fanzo et al. 2011). Limited data are available to make conclusions about the relationship between agrobiodiversity and diets (Jones et al. 2019). In addition, food and nutrition capacity of landscapes/land-use systems in terms of amounts of foods and nutrients provided is virtually unknown to science (Toledo & Burlingame 2006) and further research is needed to inform policymakers and to navigate practitioners to design nutrition-sensitive landscapes (Broegaard et al. 2017; Powell et al. 2015).

The discussion about the importance of production diversity and markets for the diets is critical because choices between the production of food and cash crops also influence competition for land, water and labour resources, and food availability (Dangour et al. 2012). While some authors find the higher importance of markets (e.g., Sibhatu & Qaim 2018; Sibhatu & Qaim 2015), others find the production diversity to be of more importance (e.g., Jones et al. 2018; Jones 2017). Other researchers are highlighting the mutually reinforcing effect of own production and markets to cover the seasonality gaps (Zanello et al. 2019). Rightly so, agrobiodiversity and diversification may contribute to diets through both own production and consumption and income pathway and markets. Either way, agrobiodiversity is a crucial resource and it should be leveraged for improving diets and nutrition (Jones 2017).

The acquisition of food biodiversity in the context of rural farming communities can be divided into two main pathways: (1) plants, animals and foods purchased in markets, and (2) plant and animal diversity obtained by cultivation or gathering in the wild (Kennedy et al. 2017). Both pathways of increasing on-farm production diversity and improving market access are recognised as ways to improve the dietary diversity of smallholders (Zanello et al. 2019; Jones 2017).

The present study will consider these two key pathways (Fig. 1). The pathway (2) could be further divided into cultivated and wild biodiversity, but we follow Kennedy et al. (2017), and among studied farming communities, we do not expect a significant consumption of wild foods. Aligning with the food environment framework (Downs et al. 2020), our pathway (1) is equal to food from natural food environments (wild and cultivated environments), and pathway (2) is equal to purchasing foods from built food environments (informal and formal markets).

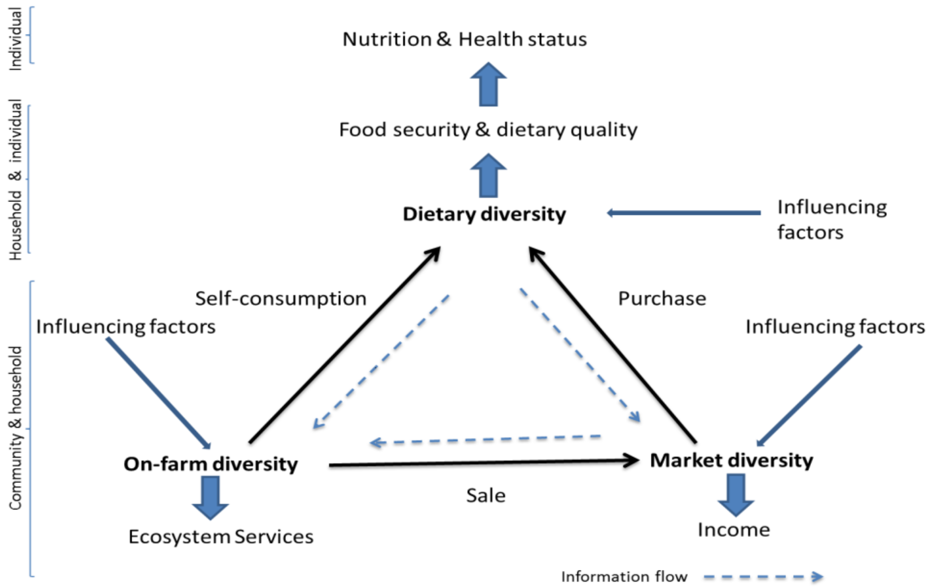


Figure 1 Conceptual model of the local food acquisition pathways and their dietary and health outcomes (adapted from Bellon et al. 2016)

This conceptual model and our research framework will address the pressing need for to increase our understanding of the nutritional importance of food biodiversity, landscapes and markets in order to inform policy and innovate practices and approaches towards biodiversity and nutrition (Fanzo et al. 2011). The more holistic socio-ecological and food system approaches appear suitable to achieve this. There is also an increasing recognition that food environment is an important factor affecting diets and nutrition (Downs et al. 2020), and that the greater the number of food environment types, the greater is the resilience with regard to diets and food security (Ahmed et al. 2020). This research aims to reveal the role of food environments and food acquisition pathways, and quantify the share of consumed foods and nutrients coming from own production (natural environments) and through the procurements on markets (built environments).

3. Research framework and research questions

The overall research framework considered a socio-ecological model of food and nutrition, which looked at the main socio-cultural and environmental factors influencing food biodiversity and its intake (Pelto et al. 2013). The concept of the study emerged from socio-ecological but also bio-cultural approaches and food system thinking. It did not look at food security and diets from a silo point of view, but it also considered food acquisition pathway with detailed assessments of the role of agrobiodiversity and food environment. It thus aimed to reveal a more complex picture of food and nutrition security and food sovereignty. Applying a holistic and interdisciplinary approach based on social and natural sciences better reflects the multifaceted nature of diets and food well-being (Gartaula et al. 2018). The methodology combined predominantly scientific disciplines of nutritional anthropology (Macbeth & MacClancy 2004; Pelto et al. 1989) and food ethnobiology (Pieroni et al. 2016). It was also aligned with the scientific assessment of indigenous peoples' food systems (McCune & Kuhnlein 2011) and it used relevant standards for measuring food intake (Gibson & Fergusson 2008; Gibson 2005), dietary diversity (FAO & FHI360 2016) and agrobiodiversity (PAR 2018).

The research framework aimed to answer four key research questions. As the dietary outcomes are the main and thus dependent variables in this research, the study aimed to identify the predictors of adequate diets (research question 1).

Besides looking at the predictors, the research aimed to quantify how much food and nutrients flow through different food acquisition pathways and from different land-use systems (research question 2).

Since fruits and vegetables are highly under-consumed in Indonesia, the third research question was about assessing the level of food plant diversity and identifying barriers and motivations for its persistence and use by people.

And the fourth research question aimed to compare food plant biodiversity and diets between the ethnic groups and thus explain how the different culture in a similar environment affects the level of agrobiodiversity and dietary outcomes. For instance, our pre-survey observation has shown that Minangkabau people maintain a high diversity of fruit and shade trees in cocoa farms through customary tradition. Mandailing, on the other hand, are hardworking rice farmers and horticulturalists with more prevalent homegardens (Tugby 1963), and it appears that they consume more substantial amounts of vegetables (pre-survey observation). Possibly, these socio-cultural differences could have an impact on diets.

Research question 1: What social or ecological factors predict a nutritionally adequate diet?

Research question 2: What proportion of consumed foods and nutrients come from different food acquisition pathways and land-use systems?

Research question 3: What is the richness of food plant diversity and what motivations and barriers affect its persistence and use?

Research question 4: How do two different cultures nested in a similar environment affect the use of agrobiodiversity and dietary outcomes?

4. Goal and objectives

The overall goal of the doctoral study was to contribute to food and nutritional security of the matrilineal Minangkabau and patrilineal Mandailing communities by a better understanding to dietary outcomes of their food systems, and through leveraging the potential of local food biodiversity. The objectives and specific aims of the doctoral study were:

Objective 1: To assess diet and food security in relation to socio-economic characteristics.

Specific aim 1.1: To characterize the socio-economic profile of the communities.

Specific aim 1.2: To describe the basic health situation of the communities.

Specific aim 1.3: To estimate food security levels.

Specific aim 1.4: To assess dietary diversity and dietary adequacy.

Objective 2: To document the diversity of food plants and characterise their importance and potential nutritionally and ethnobotanically.

Specific aim 2.1: To document agrobiodiversity and associated traditional knowledge.

Specific aim 2.2: To identify motivations and barriers to consuming local foods.

Specific aim 2.3: To reveal changes in the use of agrobiodiversity compared to the past.

Specific aim 2.4: To quantify contribution and potential of agrobiodiversity for dietary diversity.

Specific aim 2.5: To identify and recommend nutrient-rich local foods.

The comparison of ethnic groups was not a particular objective or aim, but it was treated like a cross-cutting issued reflected across both objectives. To achieve the overall goal and to have an impact on the ground, this study applied a research-for-development approach, which combined both scientific assessments with applied intervention in practice. Therefore, the findings from research objectives 1 and 2 were transformed into outputs such as community publications and workshops. These outputs aimed to share the findings and raise awareness on the importance and potential of food biodiversity with an expected impact on a) improved human nutrition and health, b) strengthened conservation and use of agrobiodiversity, c) increased food system resilience and food security. Fig. 2. demonstrates the expected impact pathway overviewing the result chain of activities, outputs, outcomes and expected impact. However, the study was not able to measure the impact in time due to limited time and budget. The description and documentation of the produced materials and events organized is given in appendix 2.

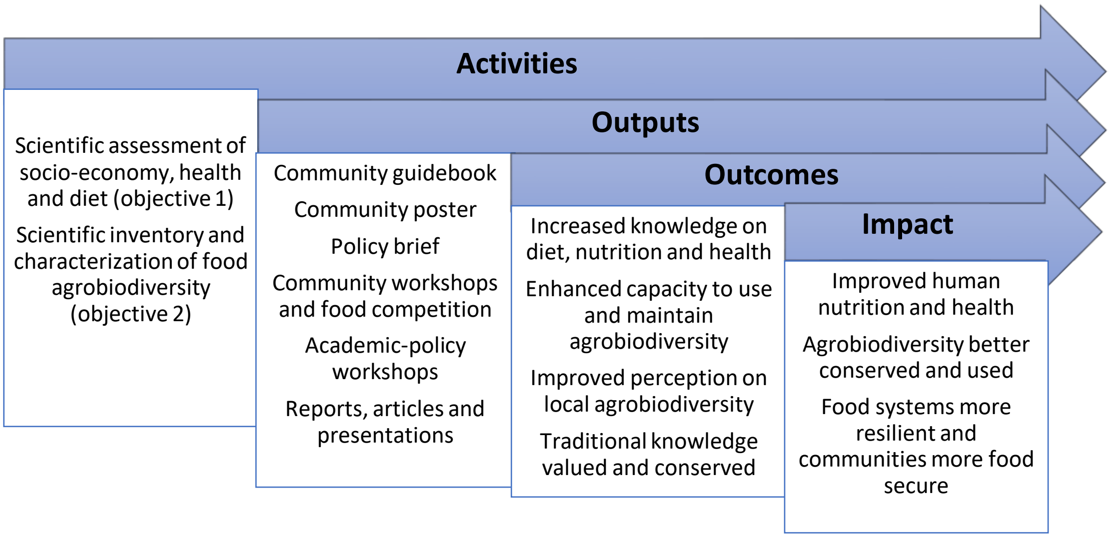


Figure 2 Expected impact pathway of the study

5. Materials and methods

5.1 Study area

West Sumatra province lies in the range of the Bukit Barisan Mountains, with the western part aligned with the Indian Ocean. The province has an area size of about 42,297 km² divided into 12 regencies (Bontoux 2009). The region falls in the tropical wet climate zone with rainy and dry seasons. The montane rainforests receive rainfall, which averages more than 2,500 mm/year (Whitten et al. 2000). The area is rich in plant and animal biodiversity with iconic species being tigers, orangutans, gibbons, Rafflesia plant, and endemic orchids. Tropical forests that in the past dominated the area are restricted to mostly protected areas and only a few customary forests "hutan adat". The province is dominated by a mosaic landscape which has been maintained by traditional land management based on the strong relationship of Minangkabau people with their land. The core of local land-use systems is based on the cultivation of wet rice and agroforestry systems dominated by trees (Michon et al. 1986). Rice fields are situated close to settlements as they need intensive care and water management. Forestland and mixed agroforestry systems are situated in hilly areas where the lower soil fertility and more frequent erosion is more suitable for growing trees than annual plants (Kosmaryandi 2005). The most important lowland crops are rice, coconut and chilli, while hill slopes are dominated by cocoa, rubber, coffee, durian, cinnamon, clove tree, and numerous other fruit or multipurpose trees. Our study area is located in the Pasaman Regency, which is isolated, landlocked and has a high cover of forests (Fig. 3). The selected regency has the highest rate of stunted children in the province, reaching 41% (MOH 2018a).

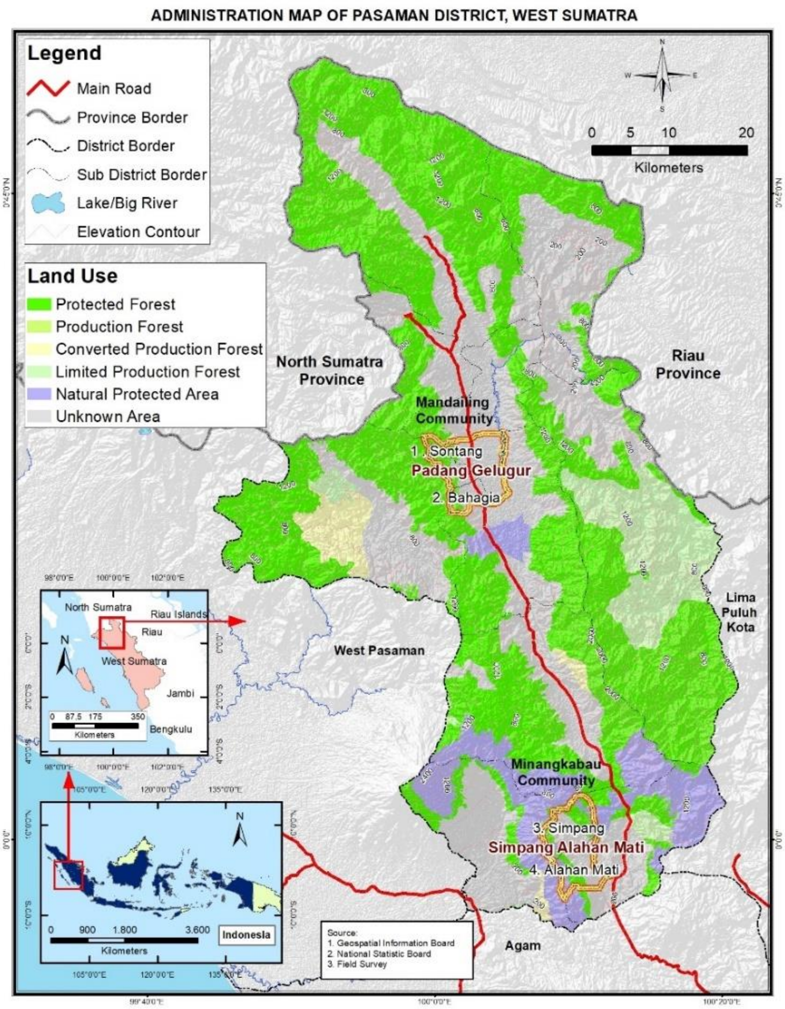


Figure 3 Map of the study area (© Lukas Pawera and Juni Muchlis Mustafa)

5.2 Study communities

From a cultural perspective, the region is dominated by the Minangkabau ethnic group and to a lesser extent by the Mandailing ethnic group, which is native and more common in the south of

North Sumatra (Lubis 2005). Our study area was located at a cultural crossroad in the north of West Sumatra and included both ethnic groups. The Minangkabau people are Muslims and are the largest matrilineal society in the world (Göttner-Abendroth 2003). In this matrilineal society, where women inherit the land and assets, women also play an essential role in transmitting knowledge within the family and clan. Minangkabau steward rich local wisdom related to agriculture, land and natural resource management, witch examples of traditional concepts and mechanism such as customary forests, protected rivers and ponds, traditional agroforestry, planting trees after marriage, and mutual work cooperation (Kosmaryandi 2005; Prof. Ervizal Zuhud, personal communication, February 2018). Minangkabau people have been studied frequently from an anthropological lens due to their unique matrilineal heritage system (Blackwood 2000).

Minangkabau rule of life: "Adat basandi Syarak, Syarak basandi Kitabullah" (Customary culture must be based on religion, religion must be based on the holy book.)

Mandailing people had initially been a Batak sub-ethnic who were Christians until the 19th century when they converted to Islam and started to adopt some elements of Minangkabau culture. Our respondents mentioned that their culture and language originated in the Tanapuli Selatan Regency of North Sumatra. In contrast to the Minangkabau culture, they adhere to the patrilineal heritage system and maintain their Mandailing language. The Mandailing community is often described as a hardworking agricultural society with indigenous traditions and community governance (Lubis 2005). Their way of life is also very much tied to the land and particularly the wet rice fields. Both communities are clan-based, where clans as social units play an essential role in socio-cultural issues and in the management of natural resources.

"Mandailing society has a life philosophy "holong and domu", that is love and affection between the community members, but also with nature and the God" (Lubis 2005).

5.3 Approach, ethics and sampling

The doctoral study employed a research-for-development approach, which combined a research phase with participatory fieldwork, followed by scientific data analysis, and ended up by a short applied intervention aiming to achieve desired outcomes and impacts on the ground. The Indonesian Ministry of Research, Technology, and Higher Education (RISTEK) granted the research permissions. The methodology was further reviewed by the ethical committee of the University of Indonesia (UI) in Jakarta, and ethical clearance was obtained (No. protocol 18-03-0291). The research followed the Code of Ethics of the International Society of Ethnobiology and all informants were familiarised with the research objectives, methods and expected results. The free prior informed consent was obtained in a written form from all the individual respondents or their spouses. The data were interpreted anonymously. The study was aligned with the goals and policy of the Indonesian National Medium Term Development Plan (RPJMN) 2015–2019, in particular with the key strategy (c) to improve the quality and nutritional value of the diet.

Having improved nutrition as an ultimate goal, our sampling of individual respondents targeted women at reproductive age (15–49 years old), as women represent a group vulnerable to malnutrition (FAO & FHI360 2016). Stratified random sampling of cocoa farmers involved in the SCPP (Sustainable Cocoa Production Programme implemented in the study area by Swisscontact Indonesia) program was applied. We interviewed 200 women individually (100 women from each ethnic group) which was estimated as a sufficient number to cover the studied population and the dietary variation. In the studied region, the total number of households involved in the SCPP Programme was 480. Out of these, 70 households were excluded due to not having a woman at reproductive age or not being an active cocoa farmer anymore. Thus, the remaining population size of 410 households was considered for the sampling framework. With a 95% confidence level and 5% margin of error, the final sample of 199 households was calculated. Thus, a total of 200 women from different households were recruited. The sampling of cocoa farming households means that the study findings may not be representative of the whole population in the region. Besides individual household visits, in-depth qualitative data were obtained through four focus group discussions (FGD) with 68 knowledgeable women participants. The sampling of FGD respondents was done purposively to select knowledgeable and active participants. Key farmers, husbands and children were allowed to join and complement the discussions whenever suitable and whenever accepted by the women participants. The Mandailing respondents were selected from the Padang Gelugur sub-district (Sontang and Bahagia villages) and Minangkabau respondents from the Simpang Alahan Mati sub-district (Simpang and Alahan Mati villages), as shown in Fig. 3. The selection of these locations followed a recommendation of the local Swisscontact staff, and it was based on the feasibility of the fieldwork, preserved landscape, and a need to improve the people's nutritional status. The main data collection for dietary assessment was conducted within March-May 2018, which was the beginning of dry season after the end of rainy season. The availability of local crops and wild vegetables was still high, but most of the fruit species were not in the fruiting season. The overall timeline of the study is provided in Appendix 4.

5.4 Individual interviews

Individual semi-structured interviews using questionnaires were conducted by a team of trained data enumerators supervised by the principal investigator (the questionnaires can be requested from the author). The enumerators had a background in nutrition and experiences with specific and challenging methods such as 24-h food recall. Prior to the interview, the ethics were followed and permission for the interview obtained (see chapter 5.3). Interviews started with assessing socio-economic characteristics, including questions of Progress out of Poverty Index for Indonesia (Schreiner 2012) and household expenditures. Subsequent was a brief section on health status and local health care options. It followed by ethnobiological/anthropological methods such as freelisting and ranking exercises (Martin 2004), perceptions on Likert Scale (Macbeth & McClancy 2004) and attitude statements (Keding et al. 2017). The attitude statements were designed a priori with the local partners to fit the study context and objectives. The next section was dietary assessment using methods like quantitative 24-h food recalls (Gibson & Ferguson 2008; Gibson 2005), fruit and vegetable frequency questionnaires, and household food insecurity access scale (HFIAS) (Coates et al. 2007). The quantitative 24-h food recalls were conducted on two non-consecutive days, one on an ordinary day and one after a market day. Collecting 24-h food recalls two times on non-consecutive days to obtain a usual intake is considered a methodological strength (Gibson and Ferguson 2008). Time of ceremonies and feasts were avoided not to encounter the unusual food intakes. To reduce the error in quantifying food portion sizes, a national photo book was used during the 24-h food recalls (MOH 2014). The guidebook covers standardized photo models of food portions (using household utensils) with weight equivalents for all common foods and ingredients in Indonesia. Due to relatively simple meals in the study area, we quantified each individual ingredient consumed with the help of the guidebook. In addition to interviews, the household food system activities were documented by participant observation directly during farming, food acquisition, cooking and eating (PAR 2018). The author and the field team were staying in the studied villages during the fieldwork, hence the participant observation was conducted continuously.

5.5 Ethnobiological food inventory of land-use systems

For each household, all land-use systems used for agriculture and food acquisition were assessed. Diversity of edible plants and animals in all land-uses was documented either by observation and measurement in case of homegardens (Vogl et al. 2004) or based on respondent memory (for more distant plots such as cocoa gardens). This might have resulted in a certain level of diversity underestimation. For ethnobiological inventory, sometimes the husband or other household members contributed to the interview in case they were more familiar with certain land-uses such as cocoa farms, which are mostly managed by men. Tended plots and natural areas such as forests, abandoned agroforests, margins, and riversides were explored with the informants via "Walk in the woods" for the existence of wild food plants (Martin 2004). Ethnobotanical information about particular edible species was noted in the field notebook by the author. Whenever possible, plant specimens were photo-documented and collected for later identification. In the field, the plant species were pre-identified, stored (pressed and preserved in an alcohol solution) and subsequently determined taxonomically by botanists (Dr. Nurainas and Ms. Rayfiqa Maulidah) from the Faculty of Biology at Andalas University in Padang. The herbarium specimens were deposited in the herbarium of Andalas University (ANDA). For well-known species, specimens were not collected, but the species were identified by the author directly in the field and documented by high-quality photographs which were consulted with the aforementioned botanists. Although the communities perceived mushrooms as wild vegetables, mushrooms were excluded due to their limited availability during the fieldwork. Main traditional markets, local groceries and food stalls were visited, but detailed market inventory was not conducted.

5.6 Focus group discussions

Qualitative in-depth data were obtained through four FGDs (one FGD per village) and in total of 68 active women took part. A trained facilitator led the FGD sessions following an open-ended questionnaire, while the assistants took the notes. Besides collecting qualitative information about local agrobiodiversity and dietary habits of the community, we applied two main participatory exercises: seasonal crop calendars (PAR 2018) and 4-cell analysis (Sthapit et al. 2012). The latter was the principal method of collecting data on changes in the use of wild and cultivated food plants along with motivations and barriers. Firstly, we prepared individual cards for each food plant, and women assessed their concurrent use by sorting cards into four cells representing the different extents of plant use. Then we discussed contemporary barriers and motivations. Secondly, we asked women to re-organize the cards to show how the situation was in the past (around 20 years ago). After reshuffling, we asked the reasons for the change in use. With the participants' permission, the discussions were recorded by an audio recorder. Women also brought traditional foods, local snacks, and samples of local food plants.

5.7 Data management and analysis

5.7.1 Data management and general data analysis

Initially, templates of Microsoft Excel sheets were created, and the data from the filled questionnaires were transcribed into these sheets by data enumerators. These sheets were merged afterwards by the author. Subsequently, the data were cleaned, and missing values were corrected, and outliers were excluded. After data cleaning, the individual and quantitative data were analyzed initially by functions and pivot tables in Microsoft Excel, followed by the descriptive and inference statistics performed in the IBM SPSS program version 22 (IBM Corp., Armonk, NY, USA). The comparison of means between ethnic groups was made by Student *t*-test when the data met the assumptions and by non-parametric alternative Mann-Whitney U test if the assumptions were violated. The relations of dependent variables (mostly nutrition indicators) with independent variables (socio-economic and biodiversity/ecological indicators) were firstly assessed by Pearson or Spearman correlations. Whenever important and possible, multiple linear regressions were run to identify explanatory variables and predictors of dependent variables. All dependent variables were checked to ensure all assumptions were met by examining the plot of residuals, homogeneity of variance and normal distribution. The data were visualized as figures in Microsoft excel, in R programming language, and by online tools such as RAWGraphs (Mauri et al. 2017). The column charts show the standard error of the mean, to indicate the uncertainty around the estimate of the mean.

The qualitative data, such as the reasons for changes in the use of food plants, were coded and categorized into emerging themes through inductive thematic analysis (Braun & Clarke 2006). The posteriori inductive approach was applied as it can better represent local views (Ryan & Bernard 2003) and as the current food system framework does not align well with the context of consumers who are simultaneously also food producers or collectors. The changes in the use of food plants were then discussed in the context of systemic drivers (FAO 2019). The coding of qualitative data was conducted using the software ATLAS.ti version 7.5.18 (Scientific Software Development GmbH, Berlin, Germany).

5.7.2 Specific data analysis within objective 1: To assess diet and food security in relation to socio-economic characteristics.

Minimum Dietary Diversity Score for Women at reproductive age (MDD-W) was calculated, and the proportion of women reaching MDD-W cut off of 5 food groups was determined (FAO & FHI360 2016). MDD-W counts the number of different food groups consumed over the last 24 hours with a maximum being 10 food groups. The Household Food Insecurity Access Scale (HFIAS) was used during the individual interviews and the HFIAS score was calculated (Coates et al. 2007). Based on the 24-h food recalls, nutrient intake was calculated manually in excel to better control for data quality and for easier inputs of many local foods. For food composition, the newest Indonesian food composition tables were used primarily (MOH 2018b), complemented by values of missing foods or specific nutrients from SMILING (Berger et al. 2013), ASEAN (INMU 2014) and USDA (2019) food composition tables. When foods did not have a composition value in cooked form in FCTs, the values of raw food were taken for analysis. The nutrients considered in this study were protein, carbohydrate, fat, energy, calcium, zinc, iron, and vitamin A, folate, and vitamin B12. No attempt was made to adjust for loss due to cooking and for bioavailability. This may have led to slight over-estimation of intake of some nutrients which suffer losses during cooking or digestion (Powell 2012).

As a comprehensive measure of nutrient adequacy, the mean adequacy ratio (MAR) was calculated as the mean of the individual nutrient adequacy ratios (Torheim et al. 2003). Individual nutrient adequacy ratios (NAR) represent the quantity of nutrients consumed per its daily recommended requirement for each individual according to age. Individual NAR were capped at 1, so that nutrients in high amounts could not compensate for nutrients consumed in lower amounts when calculating MAR (Lachat et al. 2018). Higher values of MAR means better fulfilment of nutritional requirements (maximum 1, which is equal to 100% of dietary adequacy). The multiple linear regressions were run using MAR as a key dependent variable to identify explanatory variables and predictors of dietary adequacy.

A proportion of women reaching the recommended dietary allowances (RDA) for Indonesians (MOH 2013) was counted. Specific RDA levels were assigned to individual women according to their age. Intakes of macronutrients (energy, protein, fat and carbohydrate) lower than 70% of the recommended allowances were classified as deficient intakes (MOH 1996). In case of micronutrients (Fe, Ca, Zn, vitamin A, C, B12, folate) women with less than 77% of the recommended quantities were considered as having deficient intakes (Gibson 2005). RDA is higher than EAR (estimated average requirement) to reflect amounts that will cover people with higher than average requirements. Although RDA is harder to reach than EAR, we opted to use RDA as there exist specific recommendations for Indonesians and as most of the recent studies also follow the RDA (e.g., Diana et al. 2019; Madanijah et al. 2016).

A Simple Poverty Scorecard for Indonesia (PPI) was used to calculate the extent of poverty likelihoods, according to Schreiner (2012). The household expenditures were counted for food and non-food expenditures and as the ratio between them. The frequencies of local health constraints were counted, and the perceived overall health status was analyzed based on self-assessed Likert scale (+2 Excellent, +1. Food, 0 Fair, -1 Poor, -2 Bad) (Idler & Benyamini 1997).

5.7.3 Specific data analysis within objective 2: To document the diversity of food plants and characterise their importance and potential nutritionally and ethnobotanically

Based on the combined agrobiodiversity assessment methods of seasonal calendars, freelisting and crop inventories, the total number of wild and cultivated food species was obtained. The diversity of currently cultivated food crops was measured as simple species richness (e.g., Sibhatu & Qaim 2018), and mean and total food crop species richness. Only currently cultivated food crops were considered for counting crop species richness. The traditional knowledge on wild food plants was measured as the number of wild food plants freelisted (PAR 2018). Crop species richness was correlated with available social and ecological variables. The predictors of traditional wild food plant knowledge were attempted to be identified by multiple linear regression. The importance of land-use systems as sources of food plants was analyzed and visualized by Chord diagram in the R programming language (EthnobotanyR package by Whitney 2020).

All food plants were categorized into the food groups of Minimum Dietary Diversity for Women (FAO & FHI360 2016). Namely: Grains, white roots and tubers, and plantains; Pulses (beans, peas and lentils); Nuts and seeds; Dark green leafy vegetables; Other vitamin A-rich fruits and vegetables; Other vegetables; Other fruits. The reason for following this grouping was that the study aimed to improve dietary diversity, and therefore it followed the nutritionally validated food groups. Nevertheless, the locally perceived categories were captured too. Condiments and mushrooms were not covered by this study. The species were identified taxonomically and the nomenclature followed The Plant List (http://www.theplantlist.org/). Besides species, we counted a broader number of plant "folk foods", since certain species provide foods from more nutritionally distinct food groups of dietary diversity (FAO & FHI360 2016). For example, one species - jackfruit (*Artocarpus heterophyllus*) is consumed either for its ripe fruits (other fruits), or unripe fruits as a vegetable (other vegetables). Therefore it belongs to two food groups and is also considered as two folk foods. In addition, certain species are locally considered as different ecotypes or folk taxa (for example, one species - water spinach (*Ipomoea aquatica*) grows wild in aquatic environments, but there is also a different cultivated type, which is planted and cultivated in gardens or fields). This case was also considered as two folk foods.

The factors and drivers of changes in food plant diversity and its use collected by 4-cell method (Sthapit et al. 2012) were analyzed qualitatively by categorizing the reasons through inductive analysis into the emerged themes: (i) availability; (ii) livelihood and lifestyle; (iii) food, consumption, health; (iv) income, marketing, economy; (v) multifunctionality/processing; and (vi) knowledge and skills. The perceptions and attitudes towards wild and cultivated food plants were characterized by analysing answers of individual respondents on defined statements through the Likert scale (Keding et al. 2017). The proportion of respondents agreeing or disagreeing (+2 Strongly agree, +1 Agree, 0 Neutral, -1 Disagree, -2 Strongly disagree) were determined. The nutrient-rich local foods were identified by reviewing their nutrient content in food composition tables, as mentioned earlier in chapter 5.7.2.

To quantify species´ contribution, underutilization and potential for diets, we proposed and calculated new quantitative indices[3]. The indices are based on the data obtained through 24-h food recalls. This innovative analysis emerged from combining two different disciplines of ethnobotany and dietary assessment. This cross-disciplinary approach resulted in a concept of "food reports" where one food report *FR* is an event when a respondent *R* consumed the species *S* in the food groups *FG* ($FG_1 \ldots FG_{10}$)[4]. The number of food reports is the core for calculating new indices, which are based on the relative importance of species for diets of a studied population (Tardío & Pardo-de-Santayana 2008). Indices are calculated while taking into account a proportion of people consuming them across one or more food groups. The numerical output values are given at the species level. Initially, all plant and animal species consumed in the last 24 hours (another period and method can be used too) are identified and categorized into the standard food groups of dietary diversity. Then, the number of food reports for the species is counted, and this number in different scenarios (actual, maximal, missed) further operates in calculations of all the indices. Below is the simplified explanation of calculating the three proposed indices:

Index 1. Species' Contribution to Diets (CD_s)

$$\mathbf{CD_s = FR_{actual} / N}$$

- FR_{actual} = Actual number of food reports for the species *S* in the food groups *FG* ($FG_1 \ldots FG_{10}$)
- N = Total number of respondents in the study

[3] Developing new quantitative indices for assessing the potential of edible species for dietary diversity. Presented by Pawera at ANH Academy in 2019: https://www.youtube.com/watch?v=9T0yj5Vlw9c
[4] 10 food groups adapted from the Minimum Dietary Diversity for Women (FAO and FHI360 2016)

Index 2. Species' Potential for Diets (PD_s)

$PD_s = FR_{max} / N$

- FR_{max} = The theoretical maximum number of food reports for the species S in the food groups *FG* ($FG_1 \ldots FG_{10}$). FR_{max} is counted as the number of food groups provided by the species multiplied by the total number of respondents in the study
- N = Total number of respondents in the study

Index 3. Species' Underutilization in Diets (UD_s)

$UD_s = FR_{missed} / N$

- FR_{missed} = Is the difference between the theoretical maximal number of food reports and the actual number of food reports for the species *S*. FR_{missed} is counted as $FR_{max} - FR_{actual}$
- N = Total number of respondents in the study

For calculation of the indices, food items were identified to the species, and the data analysis was performed at the species level. The indices determined the most important, underutilized, and most promising species. The species which are a source of foods from more than one food group have a high potential for diets (multi-food group species).

6. Results

6.1 Results of objective 1: To assess diet and food security in relation to socio-economic characteristics.

6.1.1 Socio-economic profile of the communities

6.1.1.1 Socio-demographic characteristics

Tab. 1 summarizes the socio-demographic characteristics of the Minangkabau and Mandailing women respondents. The sampled women were mostly the wives of cocoa farmers and their mean age was 42 years old. The mean distance to local market was estimated to be 7 minutes (by motorcycle) by Minangkabau women and 6 minutes by Mandailing women. However, the occurrence and frequency of markets, shops, and food stalls are higher in the Mandailing area, which is located directly on the main road, contrasting to the Minangkabau area which is more remote and is accessed by the minor road only. In terms of the number of households, the majority had four, five or more than six household members. In the case of education, most of the women completed elementary school or junior high school (SMP).

Table 1 Socio-demographic characteristics of the women respondents

Socio-demographic characteristic	Mandailing (n = 100)		Minangkabau (n = 100)		Total (n = 200)	
	n	%	n	%	n	%
Number of household members						
One	0	0%	1	1%	1	1%
Two	11	11%	9	9%	20	20%
Three	15	15%	15	15%	30	30%
Four	26	26%	27	27%	53	53%
Five	16	16%	28	28%	44	44%
Six or more	32	32%	20	20%	52	52%
Education level reached						
No school	1	1%	3	3%	4	2%
Elementary school	29	29%	50	50%	79	39.5%
Junior high school (SMP)	36	36%	13	13%	49	24.5%
Vocational senior high school (SMK)	12	12%	5	5%	17	8.5%
Senior high school (SMA)	17	17%	21	21%	38	19%
University	5	5%	8	8%	13	6.5%

6.1.1.2 Socio-economic status and poverty levels

The Poverty Scorecard for Indonesia (Schreiner 2012) was used to estimate the extent of poverty likelihood among the studied communities. The poverty likelihood is the probability that the household has per capita expenditure below a given poverty line. In general, Mandailing households reached a slightly higher likelihood of living in poverty (median of 87.7% likelihood that a household is in poverty of living under 2.5 USD per capita per day) compared to Minangkabau households (median of 79.7% likelihood). But the difference is not significant (t = -1.611; p = 0.109), and we can say that the prevalence of poverty was high in the study area regardless the ethnicity. A detailed distribution of households and their likelihood of living in poverty under 2.5 USD/per capita/per day is shown in Tab 2.

Table 2 Poverty scores and likelihood of living in poverty under 2.5 USD/day per capita

PPI Score[1]	Poverty likelihood (%)	No. of Minangkabau households	No. of Mandailing households	Total no. of households
0-4	99.6	0	0	0
5-9	99.0	0	0	0
10-14	98.3	0	0	0
15-19	96.5	1	2	3
20-24	95.2	9	5	14
25-29	91.5	17	11	28
30-34	87.7	10	9	19
35-39	79.7	19	16	35

40-44	68.4	14	14	28
45-49	54.7	14	21	35
50-54	40.1	4	8	12
55-59	26.9	2	6	8
60-64	17.6	8	7	15
65-69	9.1	1	1	2
70-74	6.9	0	0	0
75-79	3.7	0	0	0
80-84	0.2	0	0	0
85-89	0.0	0	0	0
90-94	0.0	0	0	0
95-100	0.0	0	0	0

[1] The lower the score, the higher the probability of living in poverty

6.1.1.3 True household expenditures

Household expenditures are commonly used in nutrition and socio-economic surveys. In our study, the particular household expenditures were counted to understand what the daily costs are, and how much money is spent on food and non-food expenditures (Fig. 4). Contrary to the preceding section on poverty likelihoods, here the Mandailing households appear to be less poor due to slightly higher expenditures. A Minangkabau household spends on average 2,973,054 IDR (211.0 USD) per month (daily 99.102 IDR equal to 7.0 USD), whereas a Mandailing household spends on average 3.110.989 IDR (220.9 in USD) per month (daily 103.700 IDR equal to 7.4 USD). The difference in total expenditures between the ethnics is not significant (Z = -0.689; p = 0.491) and confirming that both poverty levels and expenditures are similar between the ethnics. On average, the number of household members in the study area is 4.4. If this is multiplied by 2.5 USD (standard poverty line), then the resulting value of 11 USD is the actual threshold which should be spent by the studied households in order to not be classified as living in poverty. In the study area, only a minority of households can be classified as not poor.

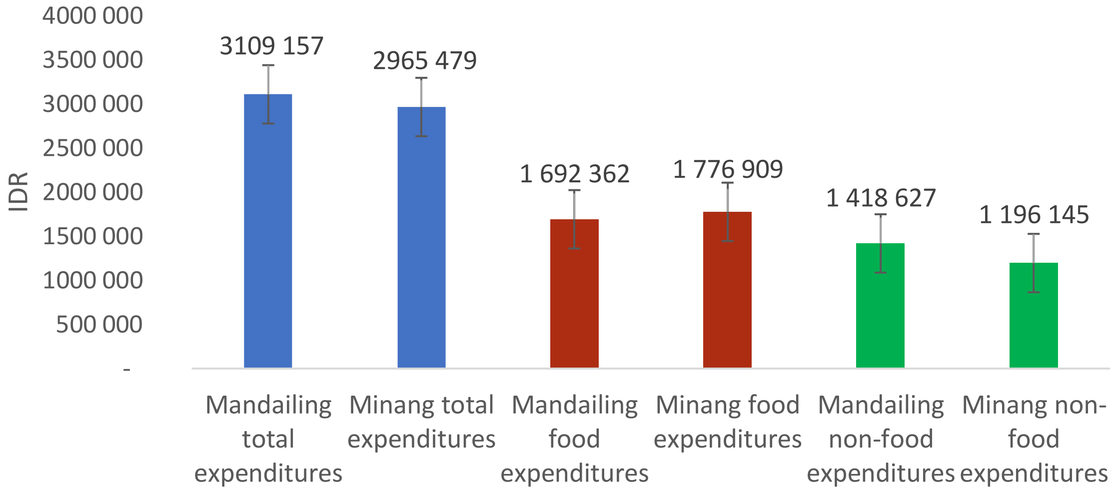


Figure 4 Monthly household expenditures in IDR (1,000,000 IDR is 68.2 USD)

When expenditures are analyzed further and converted to a ratio of food to non-food expenditures, the ratio is 1.49 (60% spent on food) in case of Minangkabau, and 1.19 (54% spent on food) among Mandailing. This shows that Minangkabau households tend to spend a 6% higher proportion of the budget on foods.

Looking at the particular food expenditures (Fig. 5), we can observe that households from both ethnics spend most of the finances on protein dishes, snacks, and rice. Notably, the spending on fruits and vegetables is very low with less than 100.000 IDR per month in both groups.

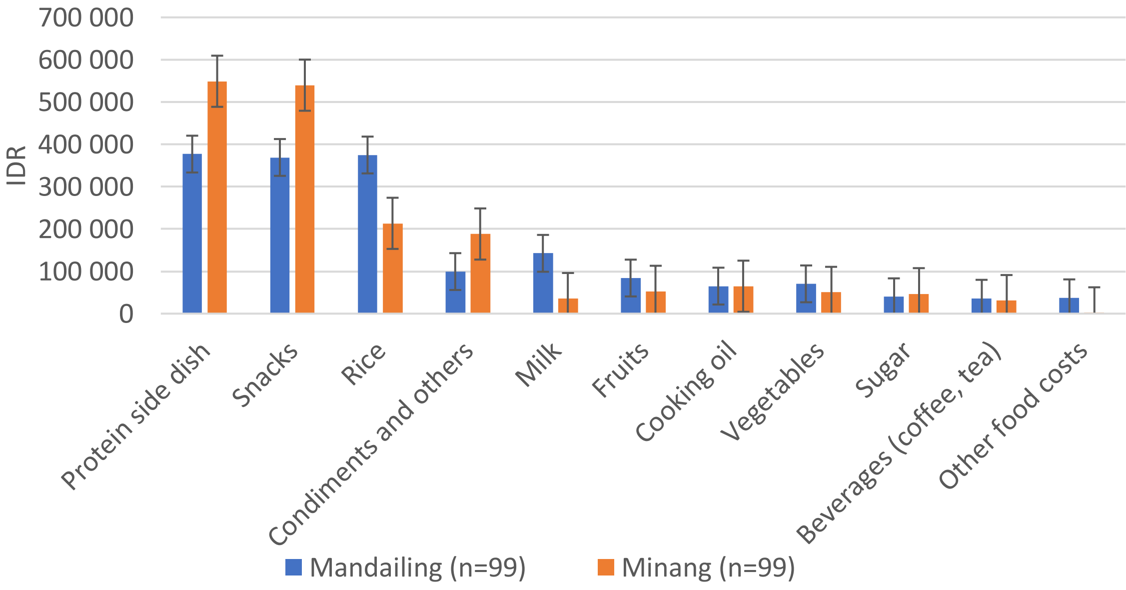


Figure 5 Monthly household food expenditures in IDR (100,000 IDR is 6.82 USD)

On the non-food expenditure side of the budget, the households spend most on energies (mainly electricity, gas, petrol), followed by cigarettes, credits and children education (Fig. 6). The Mandailing community is spending slightly more finances on the majority of non-food types of expenditures.

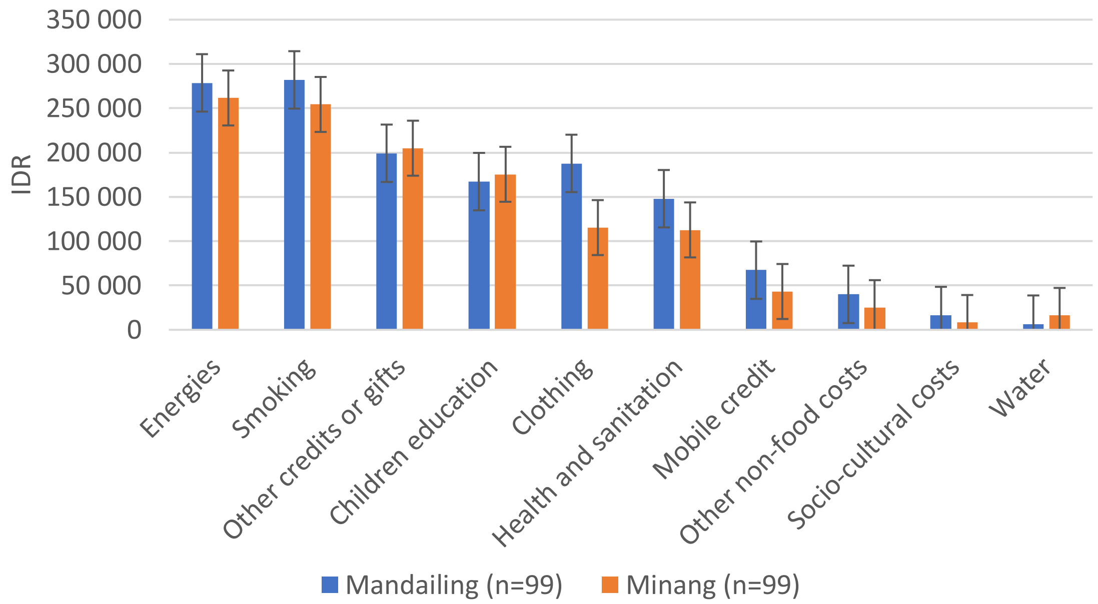


Figure 6 Monthly household non-food expenditures in IDR (100,000 IDR is 6.82 USD)

6.1.1.4 The main sources of communities' income

We did not measure the exact income of the communities, but we captured all the sources of household incomes according to their perceived importance. Fig. 7 demonstrates that farming is by far the most crucial income for both studied cocoa farming communities. As expected, cocoa production is the most important source of income, followed by the production of rice, rubber and areca nut. Besides farming, some households also derive their income from small-scale mining, operating a food stall (warung), trading goods or being a teacher. Note that the figure is showing only the most regular incomes sources with minor activities not displayed.

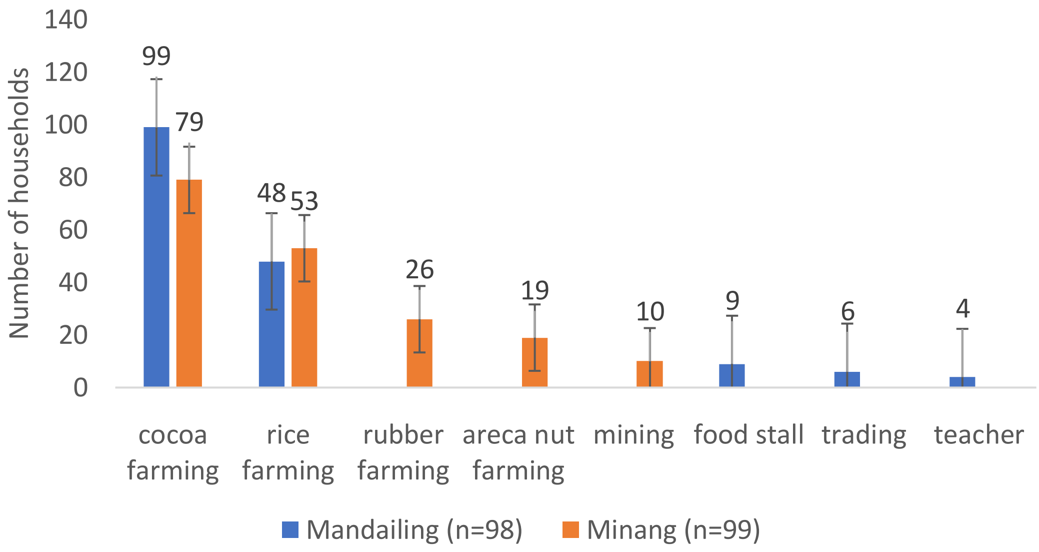


Figure 7 The most important household income sources

6.1.2 Health of the communities

6.1.2.1 The most common health problems and health care options

The five most prevalent self-reported health problems (within the last year) were flu/cough (54%), followed by gastritis (17%), rheumatism (14%), high uric acid (10%), and hypertension (9%) among Minangkabau women. Among the Mandailing women, the most common health constraints were flu/cough (22%), high uric acid (20%), rheumatism (16%), headache (9%), and fever (8%) (Tab. 3). These are quite common health disorders in West Sumatra (MOH 2018). Only high uric acid is not reported from the region, perhaps as it is not a disease itself but rather an intermediate symptom contributing to other health disorders. These findings were used to develop recommendations for the communities on how to tackle identified health constrains. It is in the community guidebook produced by the study (Pawera et al. 2018).

Assessment of the health care options revealed that around half of the women tend to consult community health workers or doctors. Around two-thirds of the respondents had health insurance (BPJS), showing that one-third of the sample is uninsured and thus vulnerable in terms of health care. Considering micronutrient supplementation, around two-thirds of the respondents were not using any supplements. From those who used supplements, the most common was the iron supplement mostly provided by community health volunteers (Posyandu).

Table 3 Basic health characteristics of the studied communities

Health and health care characteristics	**Mandailing (n=100)**		**Minangkabau (n=100)**		**Total (n=200)**	
	n	**%**	**n**	**%**	**n**	**%**
The most common health problems (currently or within the last year)						
Flu/cough	22	22%	54	54%	76	38%
Uric acid	20	20%	10	10%	30	15%
Rheumatism	16	16%	14	14%	30	15%
Headache	11	11%	10	10%	21	11%
Gastritis	8	8%	17	17%	25	13%
Hypertension	6	6%	9	9%	15	8%
Fever	8	8%	5	5%	13	7%
Low blood pressure	8	8%	4	4%	12	6%
Local health care options						
Community health worker/doctor	41	41%	71	71%	112	56%
Buy medicine in open market	26	26%	10	10%	36	18%
Medicinal plants	12	12%	3	3%	15	8%
Buy medicine in pharmacy	6	6%	2	2%	8	4%
Self-treatment	0	0%	3	3%	3	12%
Traditional healer	0	0%	0	0%	0	0%
% of women having health insurance/BPJS						
No	37	37%	25	25%	62	31%
Yes	63	63%	74	74%	137	69%
% of women taking micronutrient supplement						
No supplement	65	65%	70	70%	135	68%
Iron supplement	20	20%	20	20%	40	20%
Vitamin A supplement	17	17%	1	1%	18	9%
Another supplement	2	2%	9	9%	11	6%
% of smokers						
No	100	100%	100	100%	200	100%
Yes	0	0%	0	0%	0	0%
Extent of physical work (in agriculture)						
% of women engaged in agricultural work	67	67%	56	56%	123	62%
Number of working hours per day	7.2	-	6.0	-	6.6	-
Number of working days per week	5	-	4.5	-	4.7	-
Extent of using chemical pesticides						
% of households using chemical pesticides	94	94%	89	89%	183	92%

6.1.2.2 Perceived health status

When women were asked about the perception of their health status using the Likert scale, most of them considered their health to be good or good enough (Fig. 8). This means that the majority of women are relatively satisfied with their health. On the other hand, around 15% of the respondents perceived their health status as bad.

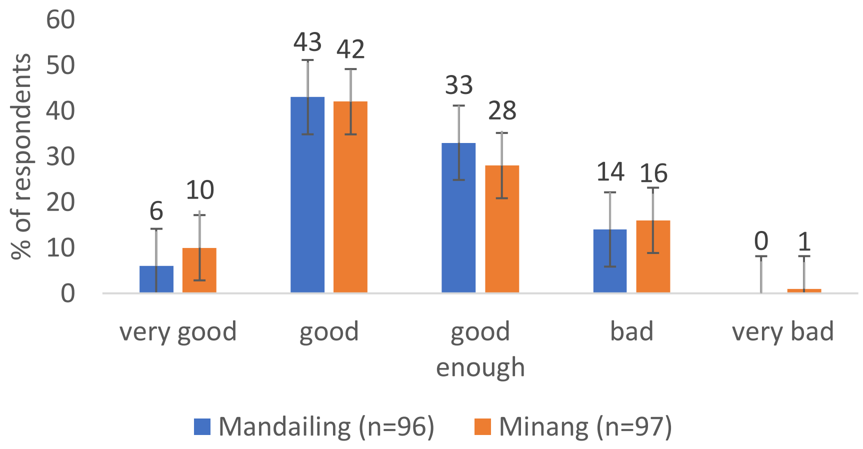


Figure 8 Women´s perception of their health status

We also analyzed the perceived quality of the diet (Fig. 9), and in this case, also most of the respondents assessed their diet as good or good enough. A proportion of women perceiving their diet to be bad is lower than the perception of bad health.

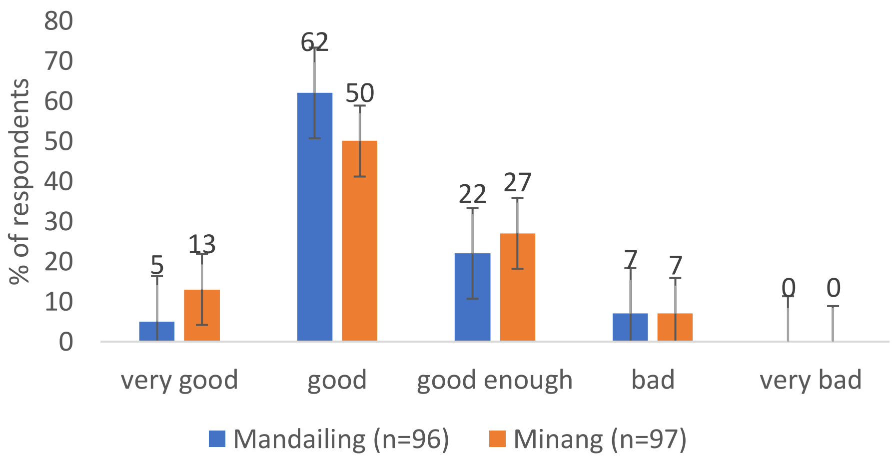


Figure 9 Women´s perception of their diet quality

6.1.3 Food security

The Household Food Insecurity Access Scale (HFIAS) identified that about 50% of the studied households were food insecure (Fig. 10). The Mandailing community showed to have a slightly higher level of food insecurity. For example, 32% of the Mandailing households are moderately food insecure, compared to 20% in the case of Minangkabau. The mean HFIAS score was 1.92 for Mandailing and 1.68 for Minangkabau, and the difference was close to statistical significance ($Z = -1.750$; $p = 0.08$).

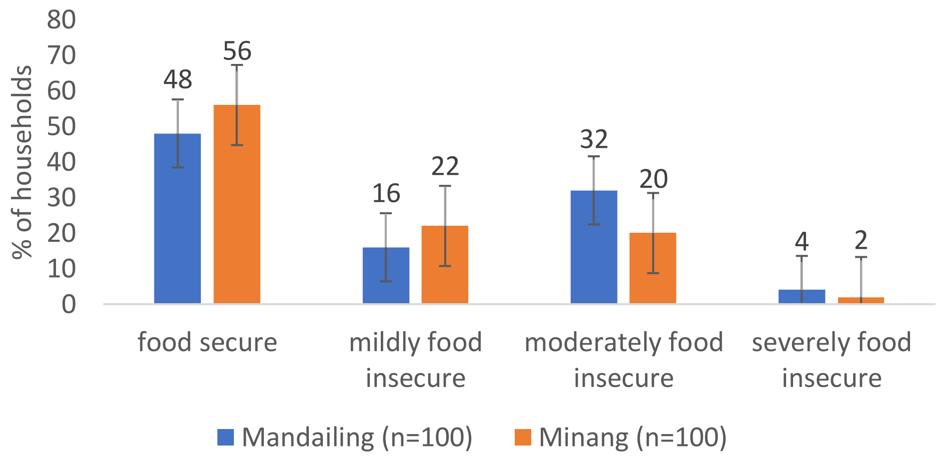


Figure 10 The household food insecurity levels based on HFIAS

We used Spearman correlations to check the relationships of food insecurity with socio-economic and agrobiodiversity characteristics (Tab. 4). Four of the available variables showed to be significantly and negatively correlated with food insecurity, which means that they have positive associations with food security. The most robust relationship was found for the education level, followed by household non-food expenditures, food expenditures, and poverty levels (the higher the score, the lower the poverty). These variables are related to poverty and wealth, which are common factors affecting food and nutritional security worldwide.

Table 4 Correlation of independent variables with food insecurity

Variable	r	p-value
Education reached	-0.190	0.007**
Household non-food expenditures	-0.189	0.007**
Household food expenditures	-0.185	0.009**
Poverty level	-0.175	0.013*
Food crop species richness	-0.102	0.151
Age of the respondent	-0.093	0.191
Number of household members	0.081	0.257
Distance to market	-0.046	0.517
Livestock species richness	0.021	0.769

* Statistically significant ($p < 0.05$), **Statistically significant ($p < 0.01$)

6.1.4 Dietary assessment

6.1.4.1 Dietary diversity

The dietary diversity of women was assessed by the MDD-W indicator (Minimum Dietary Diversity Scores for Women at Reproductive Age) following FAO & FHI360 (2016). Different food groups are sources of various macro- and micronutrients, and the more food groups consumed, the better the micronutrient adequacy (Kennedy et al. 2007). When combining two 24-h food recalls into a usual intake, the mean dietary diversity score of Mandailing women was 4.57 and 4.14 for Minangkabau women (Fig. 11). In both food recall 1 and food recall 2, Mandailing women reached significantly higher dietary diversity ($Z = -2.969$; $p = 0.003$; and $Z = -2.729$; $p = 0.006$, respectively). The overall proportion of women reaching the minimum dietary diversity of at least 5 food groups was 39% for food recall 1 and 51% for food recall 2. Within the food recall 1, only 30% of Minangkabau and 47% of Mandailing women consumed a diverse diet, whereas during the food recall 2, 43% of Minangkabau and 59% of Mandailing women reached a diverse diet.

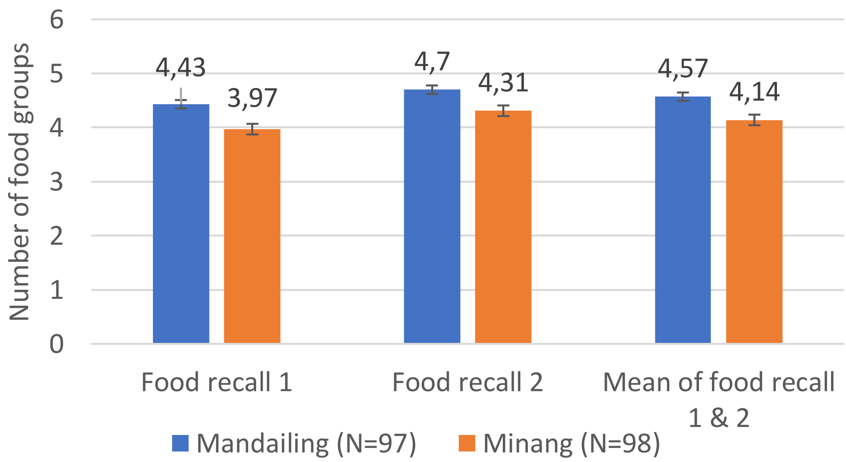


Figure 11 Dietary diversity score of women at reproductive age (MDD-W score)

When looking at the individual food groups consumed in the last 24 hours (food recall 2 analyzed due to higher food and dietary diversity), not surprisingly, the Starchy staples were consumed by all women from both ethnics (Fig. 12). The next most consumed food group was Meat eaten by a majority (81% of Mandailing and 90% of Minangkabau women). This indicates that the meat is accessible and affordable, however, it is consumed in small amounts, mostly in the form of a small or medium portion of fish (on average, 81 grams of meat per person per day). Another animal-based food group – Eggs, was consumed to a much lower extent by 28% and 25% of Mandailing and Minangkabau women, respectively. Dairy products were not consumed at all, as there is no tradition of consuming milk or its products. The nutritious food group of Leafy vegetables was consumed by 73% of Mandailing and by 51% of Minangkabau women. While Leafy vegetables were more commonly consumed by Mandailing, the Other vegetables were consumed slightly more by Minangkabau (68%) than by Mandailing women (55%). The nutritious group of Pulses was consumed much more by Mandailing women (61%) compared to Minangkabau women (35%). Other fruits are more widely consumed among Mandailing women (49%) compared to Minangkabau women (31%). In the case of Vitamin-A rich plants, and Nuts and seeds, both communities consumed them very rarely with less than 10% of the respondents.

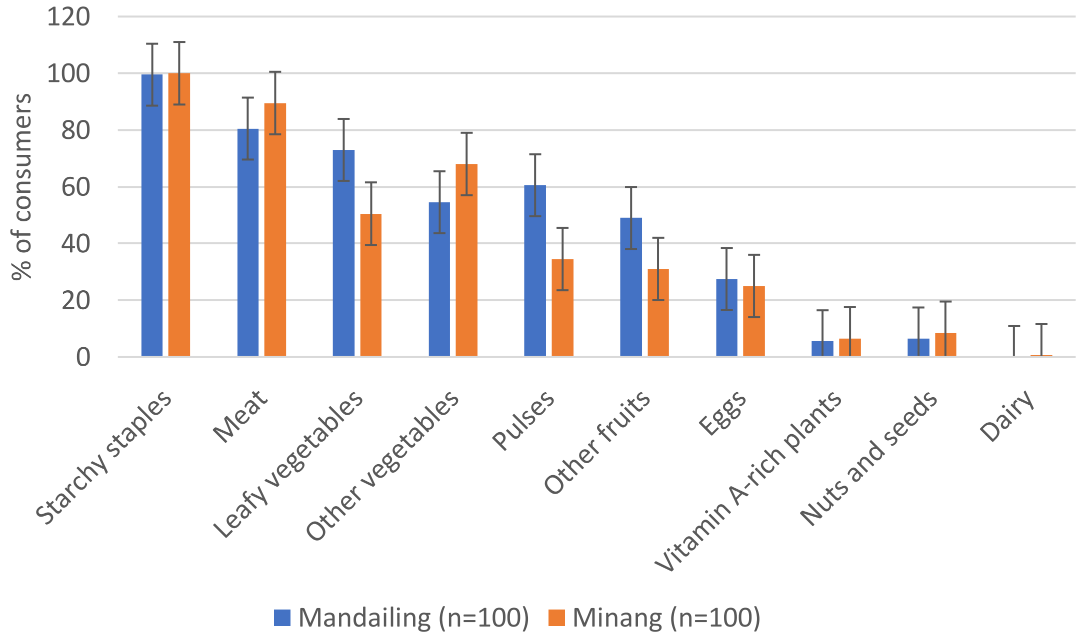


Figure 12 Proportion of women consuming particular food groups (food recall 2)

During the data collection period, most of the fruit species were not in the fruiting season, and therefore, the fruit intake was very low. The limitation is that we were not able to revisit the study area during the main fruiting season. Local vegetables, including some wild plants, were found to be consumed quite commonly. However, in general, many of the local species were found to be consumed rarely or in small amounts. The core of the diet consists of several preferred species. Fig. 13 demonstrates the difference in food groups consumed by women who reached a diverse diet (5 or more groups) and those who did not reach it.

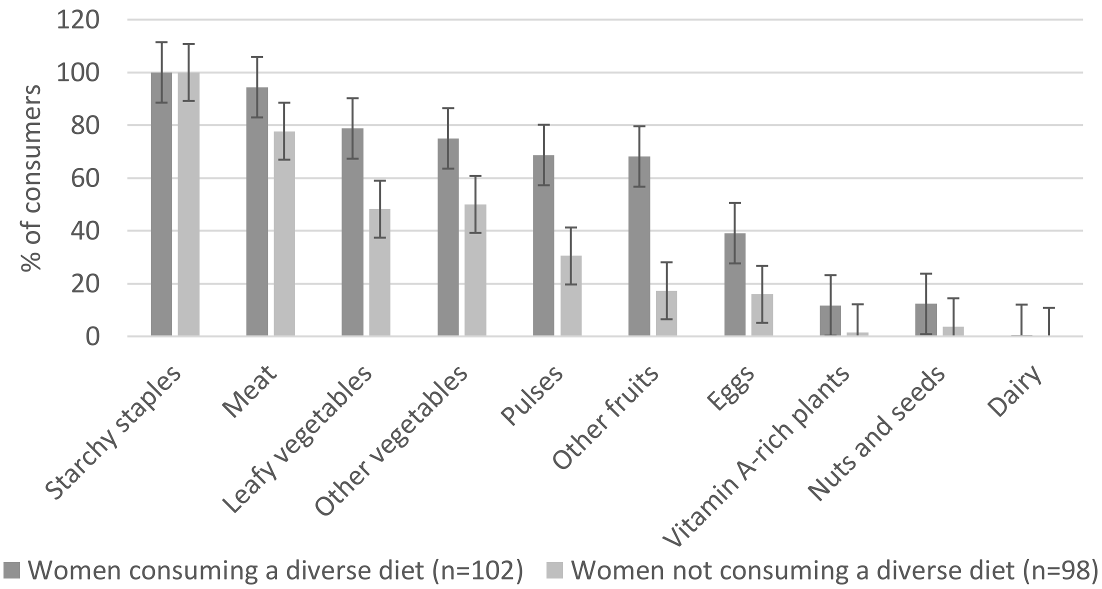


Figure 13 Food group consumption compared between women reaching and not reaching a diverse diet (food recall 2)

This figure illustrates the gap in dietary diversity, and it shows which food groups could likely feasibly diversify the diets (positive deviance approach). An enormous dietary gap and potential at the same time are found in food groups of Other fruits (51% difference), followed by Pulses (39% difference), Leafy vegetables (31%), and Other vegetables (25%). Although with a less dramatic gap, there is a difference also in the consumption of Eggs (22%), Meat (16%), Vitamin A-rich plants (11%), and Nuts and Seeds (8%).

The correlations and regression analysis were conducted to identify associations and predictors of dietary diversity, but any of the available variables showed a statistically significant relationship. Therefore, the predictors of dietary diversity are not presented here, but the associations are given later for dietary adequacy, where significant relationships were detected.

6.1.4.2 Quantitative food intake

Based on two quantitative 24-hour recalls, the mean usual intake was calculated. Tab. 6 shows the usual intake of MDD-W food groups, where in addition to the 10 groups which compose the score, optional groups were added (Savory/fried snacks, Sugared beverages, Sweets, and Condiments) to complete the picture of the dietary pattern. We can observe that Starchy staples have by far the highest mean intake of 519 grams a day. Next is meat with 81 g, other vegetables with 57 g, and oils and fats with 51 g. Comparing the ethnics, Mandailing women consumed significantly more of Other fruits (+38 g; (p < 0.01), Pulses (+37 g; p < 0.01), Leafy vegetables

(+22 g; p < 0.01), and Condiments (+ 2 g; p < 0.01). Minangkabau women had higher intakes of Other vegetables (+30 g; p < 0.05) and Sugared beverages (+1 g; p < 0.05).

Table 5 Mean intake of MDD-W food groups (in grams)

MDDW food group	Mandailing[1] (n=100)	Minang[1] (n=100)	p-value	Combined[1] (n=200)
Starchy staples	526.9 ± 172.3	516.2 ± 171.1	0.506	521.5 ± 171.8
Meat	78.7 ± 50.2	84.2 ± 51.2	0.483	81.4 ± 50.8
Other vegetables	42.3 ± 46.1	72.2 ± 84.7	0.001*	57.4 ± 69.9
Other oils and fats	45.9 ± 24.2	56.0 ± 28.9	0.034	51.0 ± 27.1
Pulses	65.9 ± 61.9	28.7 ± 39.4	0.000**	47.2 ± 55.1
Other fruits	65.8 ± 74.4	28.3 ± 41.1	0.000**	46.9 ± 62.9
Leafy vegetables	49.9 ± 43.5	28.4 ± 31.5	0.000**	39.1 ± 39.5
Eggs	20.1 ± 26.6	21.9 ± 32.4	0.941	21.0 ± 29.7
Sugared beverages	13.5 ± 29.6	14.7 ± 14.6	0.001*	14.1 ± 23.3
Sweets	10.6 ± 22.9	12.2 ± 25.1	0.461	11.4 ± 24.0
Savory/fried snacks	11.6 ± 22.2	5.8 ± 11.7	0.272	8.7 ± 18.0
Vit. A-rich plants	7.1 ± 31.2	3.6 ± 13.0	0.275	5.4 ± 23.9
Nuts and seeds	2.1 ± 5.3	3.2 ± 9.3	0.962	2.6 ± 7.6
Condiments	2.5 ± 4.6	1.0 ± 6.4	0.000**	1.7 ± 5.6

[1] All values are usual intake means in grams with a standard deviation
* Statistically significant (p < 0.05), **Statistically significant (p < 0.01)

Below, Fig. 14 expresses the percentual contribution of food groups to the total dietary energy intake (Kcal). Starchy staples, Oils and fats, and Meat groups are the main contributors to dietary energy. Combining the whole sample, the contribution of non-starchy foods to total energy intake is 45%.

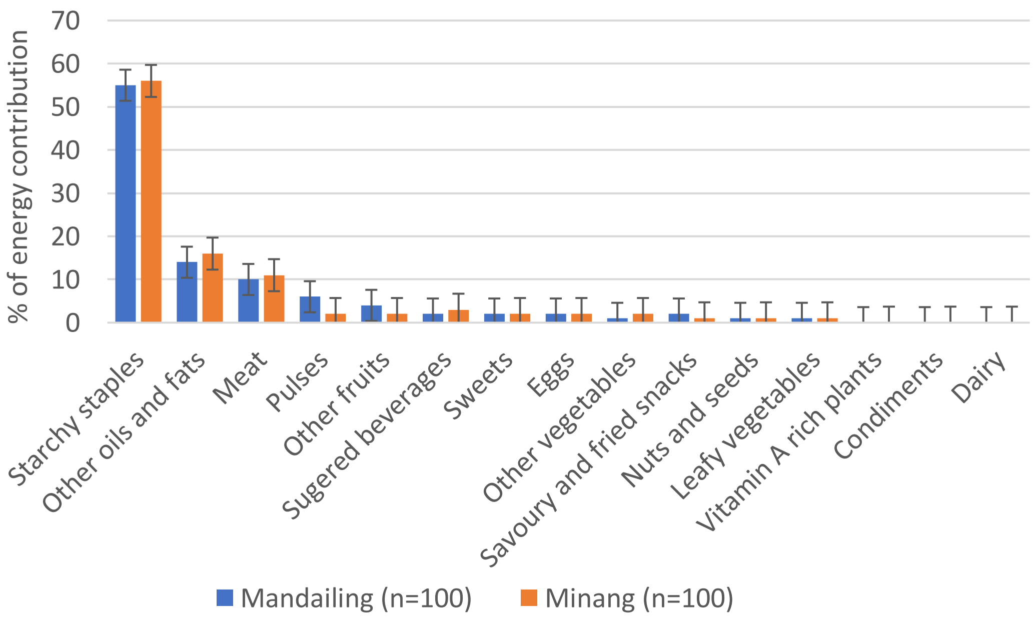


Figure 14 Contribution of 15 different food groups to total dietary energy intake

Complementary to standard and globally applicable MDD-W food groups, we also calculated the mean intakes of food groups specified by the Ministry of Health of Indonesia in the dietary guidelines of Indonesia (MOH 2014a). Additionally, we added a very important and healthy food group promoted by WHO – Fruits & vegetables (WHO 2003). The actual mean intakes of the respondents were compared to the recommended daily intakes in Tab. 6. We can observe that recommended daily intakes were reached for Cereals & tubers, Protein foods and Added oil in some cases, depending on the oil type used. The remaining food groups such as Fruits & vegetables did not reach the recommended amounts.

Table 6 Mean intake of food groups specified by WHO and Ministry of Health of Indonesia

Indonesian and WHO food groups	**Food intake (in grams)**			**Recommended daily intake (g)**
	Mandailing[3] (n=100)	**Minang[3] (n=100)**	**Combined[3] (n=200)**	
Cereals & tubers[1]	526.7 ± 172.3	516.2 ± 171.1	521.5 ± 171.2	300-400
Protein foods[1]	166.8 ± 81.5	137.9 ± 70.5*	152.3 ± 77.5	70-140
Fruits[1]	72.3 ± 87.7	29.8 ± 42.4**	51.0 ± 71.9	100-150
Vegetables[1]	92.8 ± 60.8	102.7 ± 86.7	97.8 ± 74.8	300-400
Added sugar[1]	4.9 ± 7.2	12.9 ± 14.1**	8.9 ±11.9	40
Added oil[1]	45.9 ± 24.1	55.7 ± 28.5*	50.8 ± 26.9	20-40
Fruits & vegetables[2]	165.1 ± 109.3	132.5 ± 97.5*	148.8 ± 104.8	400

[1] Food groups with recommended daily intake in dietary guidelines of Indonesia (MOH 2014a)
[2] Food group promoted by WHO (WHO 2003)
[3] All values are usual intake means with a standard deviation
* Statistically significant ($p < 0.05$), **Statistically significant ($p < 0.01$)

Subsequently, we looked at the exact proportion of women who reached the recommended minimum intake of these food groups (Fig. 15). It became evident that the majority of women reached recommended amounts of Cereals and tubers (89%) and Protein foods (87%), however, the tremendous gap in the low intake of vegetables and fruits was confirmed. Only 19% of women consumed the recommended amount of fruits during the surveyed season and just 2% consumed enough of vegetables. Minangkabau consumed a significantly lower amount of Fruits (-43 g; $p < 0.01$), Protein foods (-30 g; $p < 0.05$), Fruits & vegetables (-33 g; $p < 0.05$); and a significantly higher amount of Added sugar (+8 g; $p < 0.01$) and Added oil (+ 10 g; $p < 0.05$) than Mandailing.

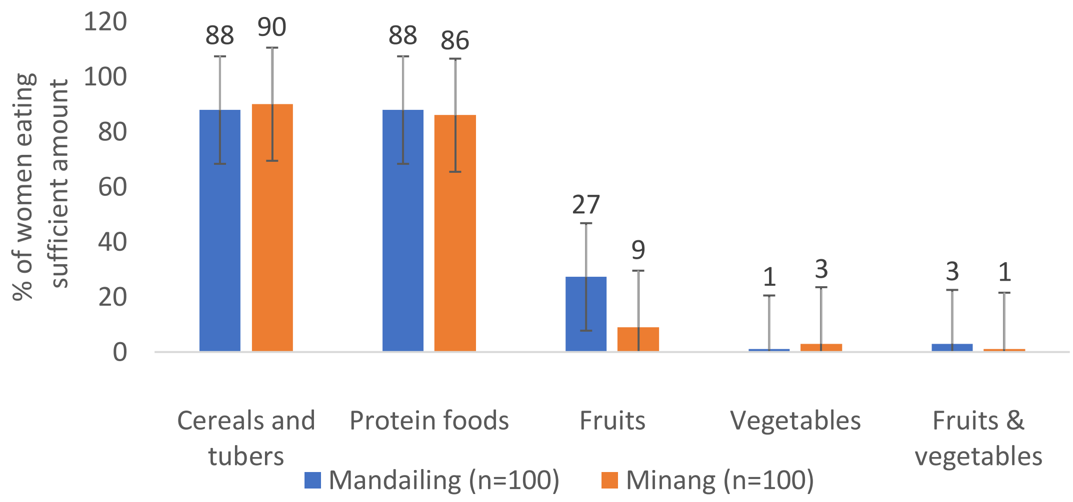


Figure 15 Proportion of women eating the recommended minimal amount of the Indonesian and WHO food groups

6.1.4.3 Dietary adequacy

To assess how nutritionally adequate the diets are, the mean usual intakes were calculated for energy, protein, fat, carbohydrate, iron, calcium, zinc, vitamin A (RAE), vitamin B9 (folate), and vitamin B12 (cobalamin). Comparing the usual nutrient intake between the ethnic groups showed slight differences (Tab. 7). The largest difference was noticed for calcium, where Mandailing women had a mean intake higher by 107.4 mg/p/d ($p < 0,0001$). Statistically significant was also their higher intake of protein (+8 g; $p < 0.01$) and iron (+2 g; $p < 0.01$). In fact, Mandailing women had higher intakes of all nutrients apart from fat, which was slightly higher among Minangkabau women (+1 g; $p > 0.05$).

Table 7 Mean usual dietary intake of Minangkabau and Mandailing women

Nutrient	Mandailing[1] (n=100)	Minang[1] (n=100)	p-value	Combined[1] (n=200)
Energy (kcal)	1766.6 ± 450.6	1713.0 ± 485.8	0.142	1739.6 ± 469.3
Protein (g)	60.6 ± 20.7	52.3 ± 17.2	0.003**	56.4 ± 19.4
Fat (g)	52.1 ± 19.8	53.3 ± 24.2	0.779	52.7 ± 22.1
Carbohydrate (g)	262.8 ± 71.9	253.4 ± 76.7	0.133	258.2 ± 74.4
Calcium (mg)	548.3 ± 216.2	440.9 ± 184.5	0.000**	493.8 ± 207.8
Iron (mg)	11.1 ± 4.2	9.1 ± 3.7	0.001**	10.1 ± 4.0
Zinc (mg)	7.1 ± 2.3	6.9 ± 2.2	0.453	7.0 ± 2.3
Vitamin A (RAE)	199.6 ± 240.4	207.7 ± 231.1	0.651	203.7 ± 235.7
Folate (Vit. B9) (µg)	152.7 ± 76.1	146.6 ± 74.0	0.605	149.6 ± 75.1
Cobalamin (V. B12) (µg)	2.9 ± 3.2	2.7 ± 2.0	0.194	2.8 ± 2.7

[1] All values are usual intake means with a standard deviation
* Statistically significant ($p < 0.05$), **Statistically significant ($p < 0.01$)

The mean adequacy ratio (MAR) combined for nine nutrients (capped at 1) was 0.64, meaning that the diet is adequate by around 64% (whereas a fully adequate diet reaching the recommended intake for all considered nutrients should have a value of 1.00, or in other words, being adequate by 100%). It must be noted that the studied diets are more adequate for macronutrients than for micronutrients, meaning that there is a bigger gap in consumption of micronutrients. The overall MAR was only slightly higher among Mandailing compared to Minangkabau women (0.65 vs 0.63) with no significant difference (t = 0.987, p = 0.325).

To uncover the specific nutrient gaps, a proportion of women reaching recommended dietary allowances (RDA) for Indonesians (MOH 2013) was calculated (Fig. 16). In the case of macronutrients, we can see that around two-thirds of the women met their RDA. Much worse was the adequacy of the micronutrients for which just a small proportion of women reached RDA. Only intake of vitamin B12 was relatively better, with over half of the women (54%) reaching its RDA. The least met RDA were found for folate (reached by 4%), followed by calcium (reached by 9%), vitamin A (reached by 12%) and zinc (reached by 34%). All these micronutrients are one of the most essential ones for human health, and their deficiencies might have severe consequences for population health and development.

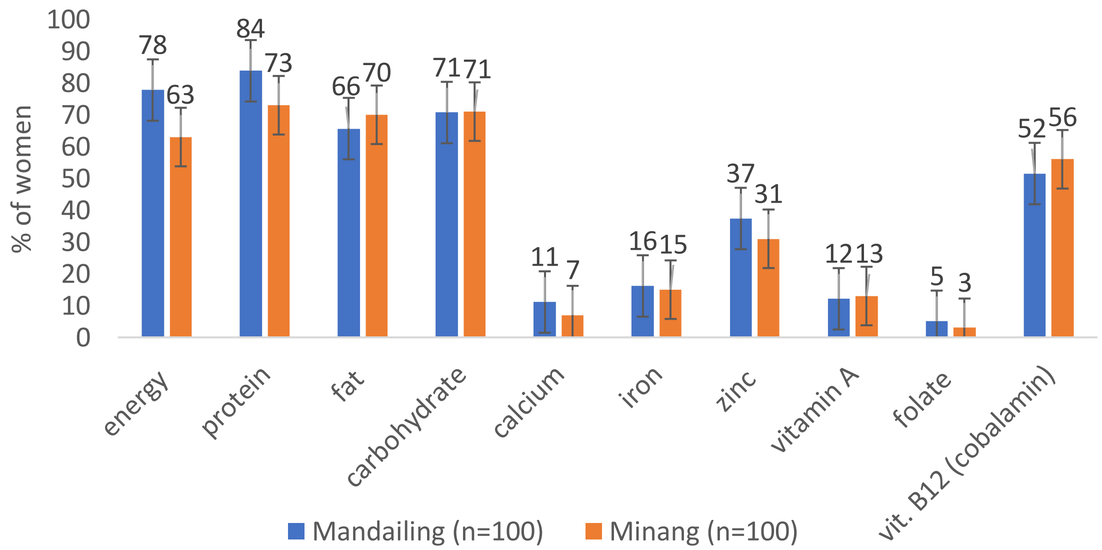


Figure 16 Proportion of women reaching the recommended dietary allowances (RDA)

6.1.4.4 Associations and predictors of dietary adequacy

The Spearman correlations identified four significant relationships with MAR (Tab. 8). The variables with a positive correlation were education level reached (r = 0.213; p = 0.03), food crop species richness (r = 0.180; p = 0.011), and lower poverty levels (r = 0.175; p = 0.014). The negative relationship was found with food insecurity (r = -0.165; p = 0.020). Here we can deduce that dietary adequacy is associated with common socio-economic factors, but also with cultivated food crop diversity.

Table 8 Correlation of independent variables with MAR (mean adequacy ratio)

Variable	r	p-value
Education reached	0.213	0.003**
Food crop species richness	0.180	0.011*
Poverty level	0.175	0.014*
Food insecurity	-0.165	0.020*
Household non-food expenditures	0.094	0.188
Age	0.065	0.365
Livestock species richness	-0.052	0.467
Distance to market	0.032	0.657
Household food expenditures	0.008	0.915
Number of household members	-0.066	0.915

* Statistically significant (p < 0.05), **Statistically significant (p < 0.01)

To better address research question 1 on what factors can predict the key variable dietary adequacy, we regressed MAR with independent variables to better identify its predictors (Tab. 9). All the variables together in the regression model gave a correlation with MAR (r = 0.350), yet they predicted the MAR only by 12% (R^2 = 0.123). The prediction model was significant (ANOVA; p = 0.005), but only 12% of variation explained means that there are likely other factors predicting dietary adequacy, and which were not captured by this study. In our final model, the MAR was predicted significantly only by cultivated food crop species richness and by household non-food expenditures. The other variables did not significantly predict MAR.

Table 9 Results of multiple linear regression predicting the MAR (mean adequacy ratio)

Variable	ß	Standardized ß	t	p-value
Food crop species richness	0.518	0.188	2.586	0.010*
Household non-food expenditures	2.28E-06	0.177	2.263	0.025*
Household food expenditures	-1.74E-06	-0.122	-1.531	0.127
Education reached	1.494	0.14	1.533	0.127
Food insecurity	-1.625	-0.103	-1.416	0.159
Number of livestock species	-1.145	-0.062	-0.854	0.394
Distance to market	0.136	0.051	0.696	0.487
Age	0.068	0.049	0.643	0.521
Poverty level	0.020	0.016	0.143	0.887
Number of household members	-0.125	-0.011	-0.105	0.916

* Statistically significant (p < 0.05)

When running an additional model for these two significant variables and controlling for other factors, they predicted MAR outcome by 5% (R^2 change = 0.052; p = 0.005), while all other controlled variables accounted for 7% of the variation (R^2 change = 0.071; p = 0.079). Lastly, when selecting only the food crop species richness as a predicting variable in the model, it predicted MAR by 3% (R^2 change = 0.031; p = 0.010) and all remaining controlled variables accounted for 9% of the variation (R^2 change = 0.091; p = 0.032). All these regression models revealed that MAR was predicted by 3% by food crop species richness, by 2% by non-food expenditures, and by 7% by all remaining variables given in Tab. 9. The richness of cultivated food crop species was found to be the best predictor of MAR, where MAR increased by 0.518 (ß) for each cultivated food crop species (one added food crop species increases MAR by 0.5%). This is an important finding showing that there is a positive linkage between the diversity of cultivated crops and dietary quality.

6.1.4.5 Food and nutrients acquisition pathways

To answer research question 2, we quantified the actual contribution of land-uses, markets and different food acquisition pathways for dietary adequacy. In Tab. 10, we can see that on average, 67% of dietary energy came from the foods purchased on the market. The second main energy contributor was own rice field (30%). The remaining sources of food are not important in terms of dietary energy. In the case of iron (which we selected as the key representative of micronutrients), the primary source contributing to its intake was also market (75%), followed by own rice field (14%) and own cocoa agroforestry (6%).

Table 10 Contribution of different land-uses and markets to total dietary energy intake

Source of food	Contribution to energy intake (%)			Contribution to iron intake (%)		
	Mandailing (n=100)	Minang (n=100)	Combined (n=200)	Mandailing (n=100)	Minang (n=100)	Combined (n=200)
Market	78%	56%	67%	83%	67%	75%
Rice field	20%	40%	30%	8%	20%	14%
Cocoa agrofor.	2%	2%	2%	8%	4%	6%
Homegarden	0%	1%	1%	1%	5%	3%
Forest	0%	0%	0%	0%	0%	0%
River/pond	0%	0%	0%	0%	2%	1%
Gift/sharing	0%	2%	1%	0%	2%	1%

When the food sources were merged into the two main pathways of a) purchasing food and b) producing or gathering own food; it became clear that a larger proportion of nutrient intakes came from purchasing food on the market (Fig. 17). Mandailing women consumed more foods purchased on the markets, whereas Minangkabau women consumed more from own sources. The difference was statistically significant for both dietary energy (Z = -5.594; p < 0,0001) and iron (Z = -5.184; p < 0,0001).

Although a larger proportion of the consumed foods and nutrients were purchased on the traditional markets, it is important to note that 95% of all foods consumed were traditional and mostly local less processed foods, while only 5% were ultra-processed and imported foods (Pawera et al. 2020).

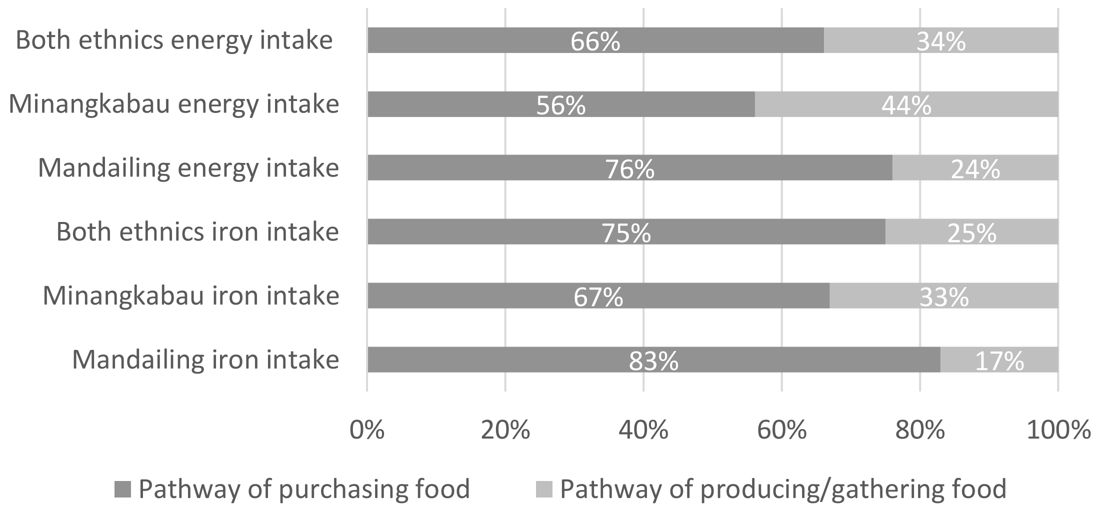


Figure 17 Contribution of food acquisition pathways to energy and iron intake

Before moving to the results of the second objective, Tab. 11 overviews and compares the main findings related to socio-economy, food security and diets between the ethnics.

Table 11 Comparison of key findings on socio-economy, food security and diets

Key characteristics compared	Mandailing	Minang	Statistical significance
Proximity to the main road and markets	Higher ↑	Lower ↓	Not significant
Poverty levels	Higher ↑	Lower ↓	Not significant
Household expenditures	Higher ↑	Lower ↓	Not significant
Food insecurity	Higher ↑	Lower ↓	Significant (p < 0.10)
Dietary diversity	Higher ↑	Lower ↓	Significant (p < 0.01)
Dietary adequacy	Higher ↑	Lower ↓	Not significant
Consumption of foods purchased from markets	Higher ↑	Lower ↓	Significant (p < 0,0001)
Consumption of foods from own production/gathering	Lower ↓	Higher ↑	Significant (p < 0,0001)

6.2 Results of objective 2: To document the diversity of food plants and characterise their importance and potential nutritionally and ethnobotanically

6.2.1 Qualitative overview of the studied indigenous food systems

This chapter consolidates and qualitatively overviews the studied food systems based on multiple methods applied, particularly individual interviews, FGDs and observations. The local food system of the studied communities is strongly linked with rice cropping and with cocoa agroforestry systems (Fig. 18a). Almost every household had these two principal land-use systems, which are used for their own food production as well as for income generation, with a highly varied ratio of subsistence to the market orientation between the households. As shown earlier (Fig. 8), the main sources of income are the production of cocoa, followed by rice, rubber and areca nut. Men are traditionally working in more remote agroforestry farms (tending the cocoa, rubber, areca nut and associated crops and shade trees), while women are fully engaged in the management of rice fields and homegardens. Food crops are grown in homegardens (kitchen gardens), agroforests and occasionally in rice fields or field patches not used for rice production. Crop diversity is generally high and around half of the households raised farm animals, mostly chicken, and more rarely duck, fish or goat (see chapter 6.2.2 below). Natural habitats such as forests, rivers, and streams are used to a smaller extent to acquire wild foods, mostly wild food plants and various types of fish.

As found by the dietary assessment (earlier chapter 6.1.4), diets are dominated by a high intake of rice, accompanied by a small amount of vegetables and meat, mostly fresh or dried fish. Fruits are consumed irregularly and with high variation due to seasonality. The traditional foods contain lots of spices (mostly chilli, onion and garlic) and many include coconut milk. Our study might have missed a few species of spices since we focused on nutritionally important food groups that contribute to dietary intake (FAO & FHI360 2016). We found that wild food plants are consumed to a small extent and rather spontaneously. In terms of food preparation, besides a few common species consumed raw (e.g., cucumber, tomato, lettuce) the majority of vegetables are consumed cooked, either stir-fried or boiled. Fruits are primarily consumed raw besides a very popular fried coated banana. Both food crops and wild food plants are cultivated or collected from natural and managed lands, as well as purchased in traditional markets, where more and more households are purchasing foods, according to the respondents. Considering the transition of food environments (Downs et al. 2020), the area can be characterized as an agrarian society with trade. The main food environment is composed of wild and cultivated food environments and with regular informal markets composed mainly of wet markets and food stalls (Fig. 18b). Although the communities still prefer and consume traditional foods, the availability and consumption of ultra-processed foods are slightly increasing.

Figure 18a) Natural food environments - traditional land-uses (rice field in Simpang village on the left; cocoa agroforestry on the right, Simpang village, 2017).

Figure 18b) Built food environments – local wet markets (food plants on the left; fish and seafood originally brought from the coastal regions on the right, Kumpulan town, 2017)

6.2.2 Food plant diversity and associated traditional knowledge

This section is answering research question 3 about the levels of cultivated and wild food plants and explanations of changes in their use.

6.2.2.1 Overall food plant diversity of the communities

Combining the seasonal calendars, dietary assessment, individual free lists and ethnobotanical inventories, we documented a total of 131 food plant species which corresponds to 167 plant folk foods (Tab. A1 in appendix 1). Surprisingly, the number of wild food plants (85 species providing 106 folk foods) is slightly higher than the diversity of cultivated food plants (79 crop species providing 98 folk foods), indicating that besides high crop diversity, the communities steward rich traditional knowledge on wild edibles (Tab. 12). Quite a high number of same species existed in both wild and cultivated forms (15% overlap).

Table 12 Diversity of wild and cultivated food plants and folk foods according to food groups

Food group	Number of species (and folk foods)[1]	Number of wild species (and folk foods)[1]	Number of cultivated species (and folk foods)[1]	Number of species (and folk foods)[1] purchased only
Starchy staples	8 (8)	4 (4)	7 (7)	1 (1)
Leafy vegetables	28 (32)	27 (27)	16 (16)	0 (0)
Other vegetables	42 (47)	28 (29)	26 (27)	2 (4)
Pulses	9 (9)	6 (6)	7 (7)	1 (1)
Nuts and seeds	6 (6)	5 (5)	4 (4)	0 (0)
Vit. A-rich plants	10 (10)	5 (5)	5 (5)	1 (1)
Other fruits	50 (54)	27 (30)	29 (32)	7 (7)
Total[2]	**131 (167)**	**85 (106)**	**79 (98)**	**12 (14)**

[1] Plant foods include different folk taxa, as well as different edible plant parts from the same species
[2] Total species number is not cumulative as some species overlap in more food groups

In addition to local cultivated and wild plants, 12 food plant species (providing 14 folk foods) were accessed only from the markets, showing the role of markets in bringing new foods. Since these were consumed, they were considered in the overall diversity in this chapter and in Tab. A1, however, they were excluded in the consequent chapters on cultivated and wild food plants. If they were excluded from the overall food plant diversity, the total number of local food plants would be 119 species and 153 plant folk foods.

The best-represented food group is Other fruits with 50 species (54 folk fruits), followed by Other vegetables with 42 species (47 folk vegetables). On the other hand, the least diverse groups are Nuts and seeds (comprising only 6 species), and Pulses with 9 species.

From the locally cultivated and collected species (excluding 12 non-local species obtained from the markets), the best-represented botanical families were Leguminosae (14 species), Arecaceae (10 species), and Anacardiaceae, Cucurbitaceae, and Poaceae (all by 6 species). Concerning plant parts, the most prevalently used were fruits (54%, including unripe fruits used as vegetables), leaves (21%, including young shoots or tender leaf stems), stems/shoots (17%, including palm hearts of 2 palm species), seeds (10%), tubers (3%) and lastly flowers (2%).

Comparing the ethnic groups (Tab. 13), the Minangkabau community maintained 121 food plant species (151 folk foods), a higher diversity compared to Mandailing community which had 108 food plant species (135 folk foods). Both communities had the highest diversity within the category of Other fruits, and the least diverse were Nuts and seeds, represented only by 5 species in each community. Minangkabau were found to steward 27 unique species which did not occur in Mandailing area. Vice versa, the Mandailing community had 13 species not existing in the Minangkabau area. However, the majority of food biodiversity overlaps (77%) and is common to both ethnic groups (101 species and 119 folk foods).

Table 13 Comparison of food plant diversity between the ethnic groups

Food group	**No. of species (and folk foods)[1] in Minang.**	**No. of species (and folk foods)[1] in Mandailing**	**No. of species (and folk foods)[1] unique to Minang**	**No. of species (and folk foods)[1] unique to Mandailing**	**No. of species (and folk foods)[1] overlapping in both**
Starchy staples	8 (8)	7 (7)	1 (1)	0 (0)	7 (7)
Leafy vegetables	23 (24)	24 (5)	7 (7)	6 (6)	17 (18)
Other vegetables	37 (34)	33 (37)	7 (7)	5 (5)	29 (32)
Pulses	8 (8)	5 (6)	3 (3)	0 (1)	5 (5)
Nuts and seeds	5 (5)	5 (5)	1 (1)	1 (1)	4 (4)
Vit. A-rich plants	10 (10)	9 (9)	1 (1)	0 (0)	9 (9)
Other fruits	52 (54)	44 (46)	7 (9)	1 (1)	44 (45)
Total[2]	**125 (151)**	**108 (135)**	**27 (29)**	**13 (14)**	**101 (119)**

[1] Plant foods include different folk taxa, as well as different edible plant parts from the same species
[2] Total species number is not cumulative as some species overlap in more food groups

6.2.2.2 Diversity of cultivated food crops

Considering all land-uses, the study documented 79 locally cultivated food plants, which provide 98 folk foods. Mandailing households cultivated 6.6 food crops on average, with a total number of 64 crop species in the Mandailing area. The most frequently cultivated crops by Mandailing farmers were cassava, rice, papaya, sweet leaf, and banana (Fig. 19). Cassava leaves are the most popular vegetable in both communities. Surprising is a high frequency of sweet leaf (*Sauropus androgynus*) in Mandailing area, whereas this nutritious vegetable is neglected by Minangkabau people. Also papaya plant is cultivated much more frequently by Mandailing farmers.

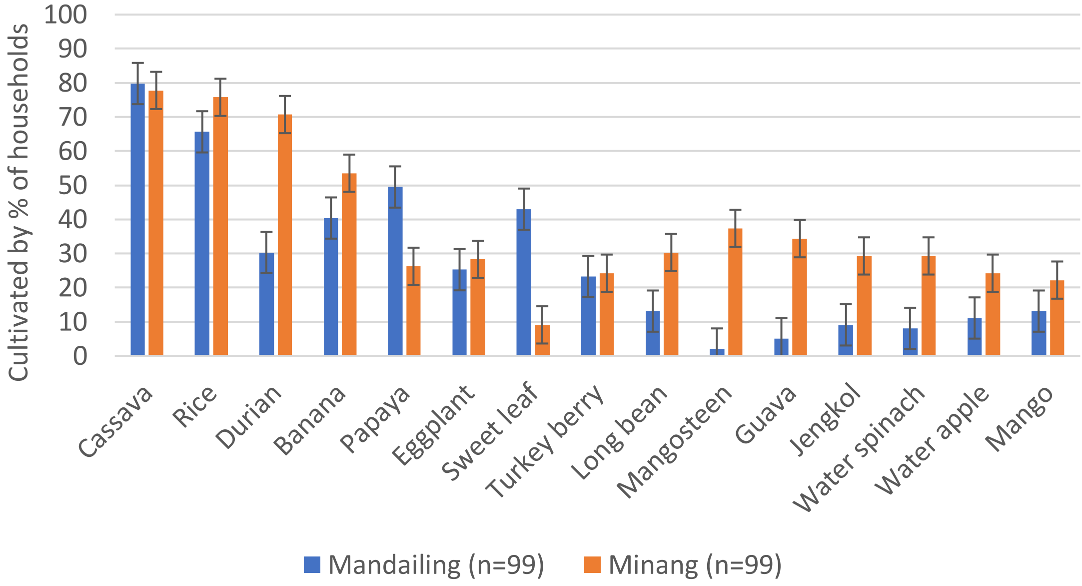


Figure 19 Frequency of occurrence of the most prevalently cultivated food crops

Minangkabau households were found to maintain a significantly higher food crop diversity cultivated with 9.6 crops on average ($Z = -3.854$; $p = 0.000$). In total, Minangkabau community cultivated 77 species of food crops. The higher crop diversity among Minangkabau is likely due to higher distance from the main road, and also as Minangkabau is the dominant and native group to West Sumatra, whereas Mandailing arrived from North Sumatra more recently. Fig. 19 shows that the most frequently occurring Minangkabau food crops were cassava, rice, durian, banana and mangosteen. Figure 19 compares that durian, mangosteen, guava, jengkol and water spinach are cultivated to a much wider extent by Minangkabau community. Besides water spinach, all are food trees that Minangkabau cultivate in traditional agroforestry system called “Parak” or “Kebun coklat” (cocoa garden since cocoa has become the main agroforestry crop).

Taking into account livestock ownership, 69% and 50% of Mandailing and Minangkabau households owned one or more kind of livestock, respectively. The chicken was by far the most prevalent. More rarely, people kept duck, fish, goat, or buffalo. Livestock was raised mainly for own consumption, but sometimes also for selling or for both purposes.

6.2.2.3 Factors associated with crop diversity

We used Spearman correlations to look at the relationships of food crop species richness with other variables (Tab. 14). The correlations revealed two positive and significant relationships: First, between food crop species richness and livestock species richness ($r = 0.154$; $p < 0.031$), showing that households that cultivate high crop diversity also maintain higher diversity of livestock species. And the second association was the age of the respondent (r = 0.152; p < 0.033), suggesting that older respondents tend to maintain higher crop diversity.

Table 14 Correlations of independent variables with food crop species richness

Variable	r	p-value
Livestock species richness	0.154	0.031*
Age of the respondent	0.152	0.033*
Food insecurity	-0.102	0.151
Household food expenditures	0.102	0.154
Poverty level	0.098	0.169
Education reached	0.089	0.211
Household non-food expenditures	-0.072	0.315
Distance to market	0.050	0.485
Number of household members	-0.014	0.841

* Statistically significant (p < 0,05)

6.2.2.4 Traditional knowledge on wild food plants

Together, the communities steward traditional knowledge on 85 species of wild food plants, corresponding to 106 plant folk foods. Comparison of traditional wild food plant knowledge between the ethnic groups showed that Minangkabau and Mandailing women listed 14.0 and 10.2 wild food plant species on average, respectively. The difference in knowledge is statistically significant (Z = -4.145; p = 0.000). We ran multiple linear regressions to determine the predictors of traditional knowledge on wild food plants, but none of our social or ecological variables significantly predicted the knowledge (p > 0.05). In the final model, all the variables together resulted in a weak correlation of r = 0.260, and they predicted the knowledge only by 7% (R^2 = 0.07). However, as mentioned earlier, Minangkabau women knew a significantly higher number of wild food plants. Fig. 20 is showing wild food plants with the highest frequency of citations based on the individual freelisting exercise. Minangkabau women were citing wild plants to a larger extent than Mandailing. The main differences can be seen on wild leafy amaranth, taro, bamboo and water spinach, which were all cited by more Minangkabau women.

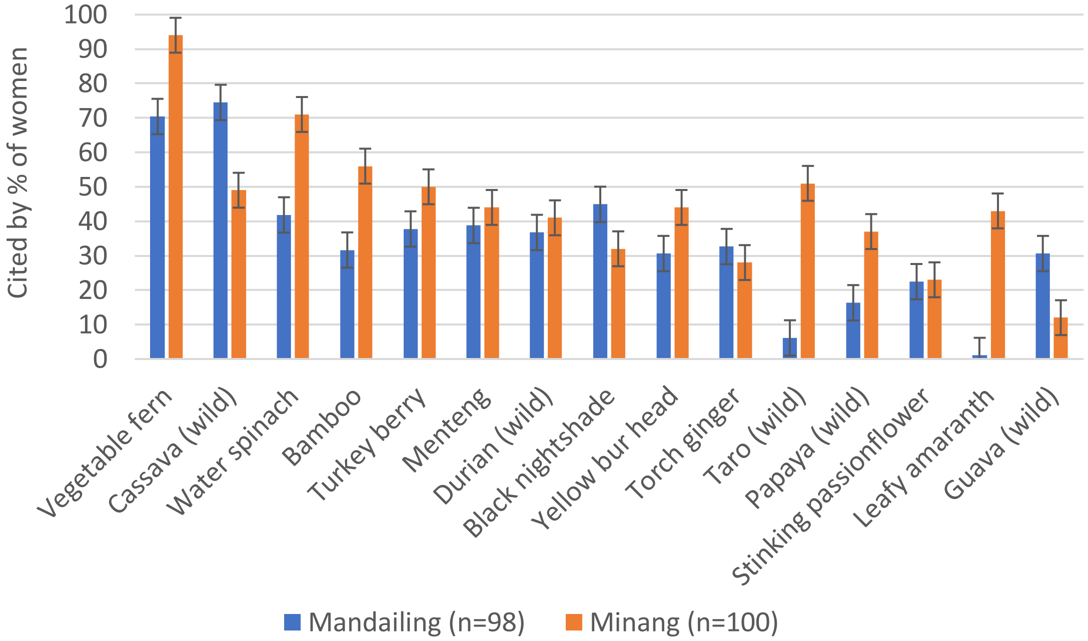


Figure 20 The most frequently listed wild food plants

6.2.2.5 The landscape's food biodiversity capacity

The importance of the local land-uses from the food provisioning role was assessed initially by the number of food plants sourced from them. In the case of both ethnic groups, cocoa agroforests showed to have the highest diversity of food plants (Fig. 21). The next were homegardens which are also very diverse. In the middle are forests and less food plant-rich are rice fields and aquatic environments. Currently, people rely more on tended plots than forests which became quite remote and less convenient to access.

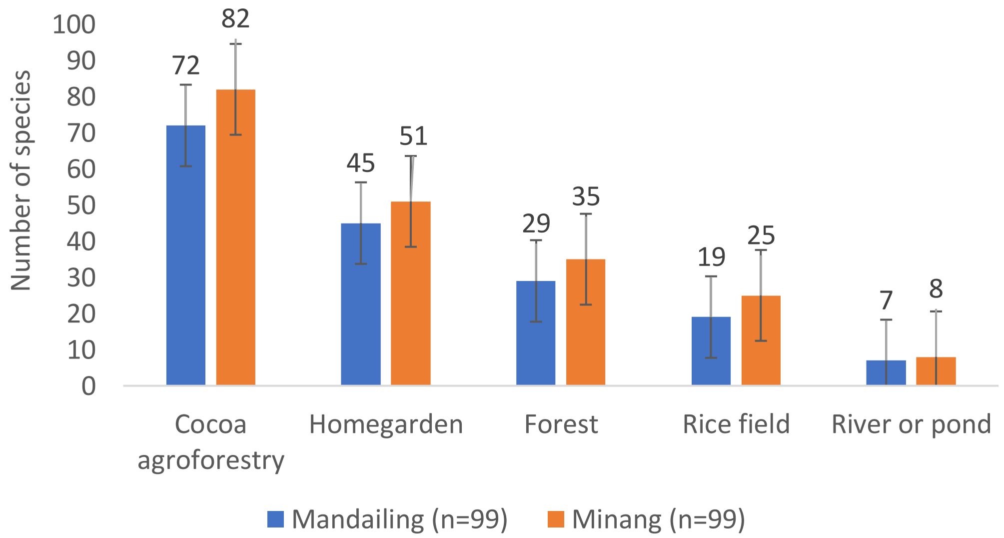


Figure 21 Total number of food plant species across the land-uses

The ten most common food plants in particular land-uses are shown in Tab. 15. In aquatic environments (river or pond) only a few species occur - mostly vegetables. All other land-uses are dominated by a mix of fruit and vegetable species. Among the most common food plants, only one species belongs to the Pulses food group – jengkol (*Archidendron pauciflorum*), demonstrating how rarely pulses occur in the landscape. The complete list of food plants and their habitats can be found in Tab. A1 (Appendix 1).

Table 15 Overview of the 10 most prevalent food plants across the local land-uses

Cocoa agroforestry[1]	**Homegarden**[1]	**Forest**[2]	**Rice field**[1]	**River or pond**[2]
Durian (51%)	Cassava (40%)	Vegetable fern (82%)	Rice (71%)	Vegetable fern (82%)
Cassava (48%)	Chilli (21%)	Bamboo (57%)	Cassava (11%)	Water spinach (62%)
Chilli (33%)	Banana (20%)	Torch ginger (29%)	Long bean (9%)	Yellow bur head (30%)
Banana (31%)	Guava (17%)	Menteng (44%)	Chilli (8%)	Taro (27%)
Papaya (27%)	Eggplant (17%)	Durian (wild) (41%)	Sweet leaf (7%)	Water mimosa (7%)
Jengkol (17%)	Soursop (13%)	Stinking passion vine (22%)	Water spinach (7%)	Elephant ear (2%)
Turkey berry (17%)	Water apple (13%)	Guava (20%)	Coconut palm (5%)	-
Mangosteen (15%)	Mango (13%)	Rambutan (wild) (19%)	Papaya (4%)	-
Sweet leaf (15%)	Papaya (12%)	Lanzones (18%)	Banana (4%)	-
Avocado (12%)	Long bean (12%)	Forest mango (15%)	Eggplant (4%)	-

[1] For plants in agroforestry, homegarden and rice field, the % shows the frequency of occurrence based on the inventory

[2] For plants in forest and river/pond, the % shows a proportion of women citing that plant-based on the freelisting exercise. Freelisting of plants documented known plants, but it did not trace the habitats of the plants. For example, vegetable fern was listed by 82% of women, and it is indicated in both forests and rivers/ponds, since the vegetable fern occurs in both land-uses (based on observations, inventory, FGD).

This is also demonstrated by looking specifically at the sources of wild food plants (Fig. 22). The figure visualizes the wild food plant diversity in particular food groups across all the land-uses. We can see that agroforests are the most diverse and that wild food plants from agroforests contribute to the following food groups: Other fruits, Other vegetables, and Leafy vegetables; and to a lesser extent Nuts and seeds, Pulses and Starchy staples.

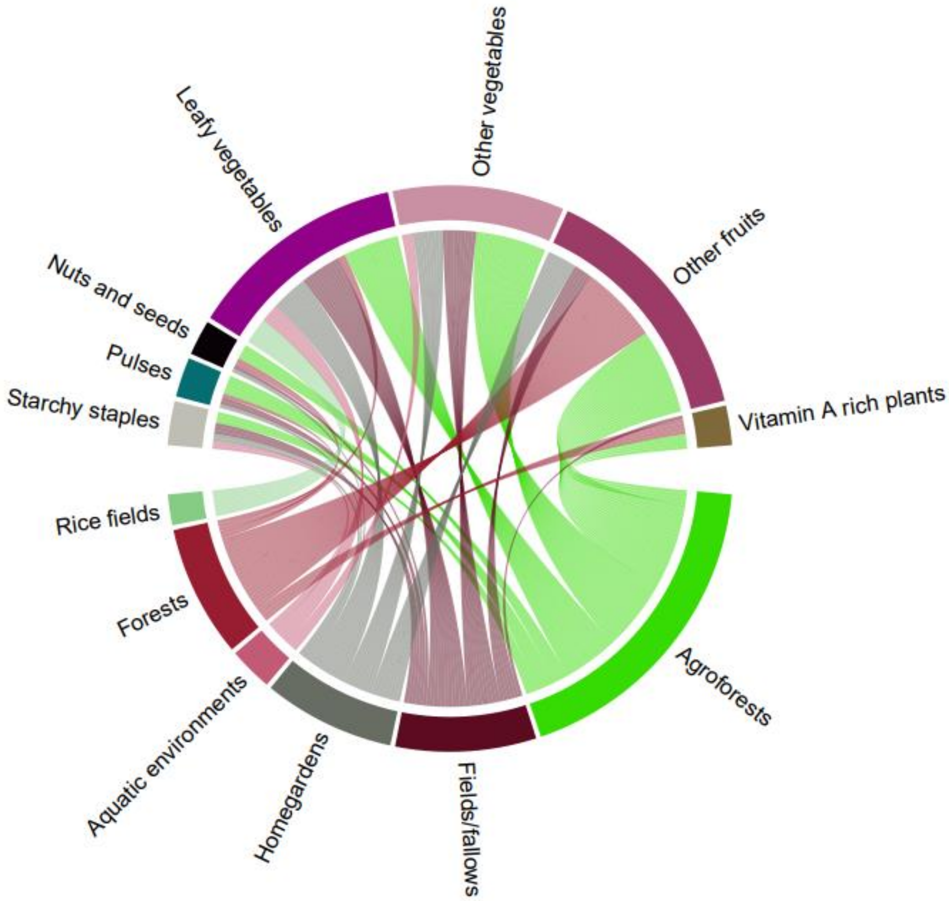


Figure 22 Land uses as sources of wild food plants in particular food groups (the thicker the stream, the more wild food plants are found in there). Adapted from Pawera et al. (2020).

6.2.3 Perceptions and attitudes towards local food plants

Perceptions and attitudes are important drivers of human behaviour. We characterized the attitudes of women towards local wild and cultivated food plants by analysing answers of individual respondents on prepared "barrier analysis statements" (Keding et al. 2017). The statements and level of the agreement are given in Fig. 23. The strongest agreement came with the statement "I would eat more wild foods if I know their nutrition and health benefits". The second best agreement reached the statement "crop diversity is important for nutrition and health". In case of disagreement, the majority of people did not agree that "Wild food plants are associated with lower social status". From these attitudes, we can note that most of the women perceive local crops and even wild food plants positively, but that the lack of knowledge on nutrition and health benefits is one of the main barriers preventing people from consuming them more.

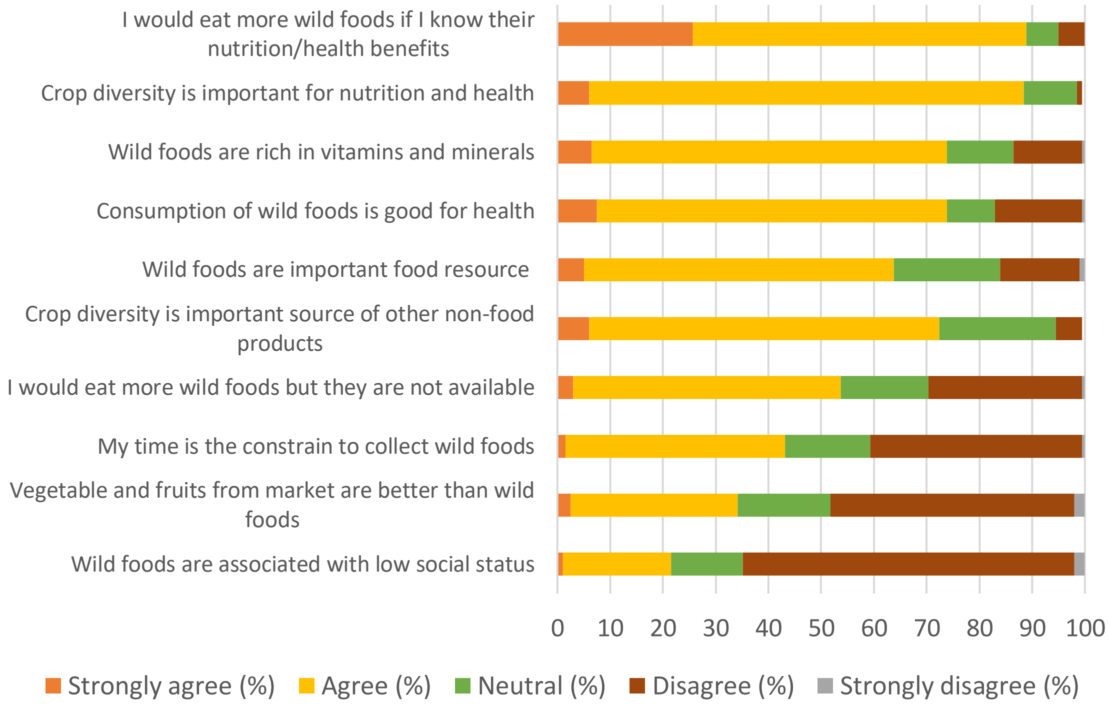


Figure 23 Attitudes of women towards consuming wild and cultivated plants

Similarly, but with a simplified 3-option scale, we compared the perceptions of women on locally produced foods versus foods from the markets. The results showed clearly that local food plants have a lower market price compared to commercialized plants purchased on markets (Fig. 24). However, both self-collected wild and cultivated plants are perceived to be tastier than plants purchased on the markets.

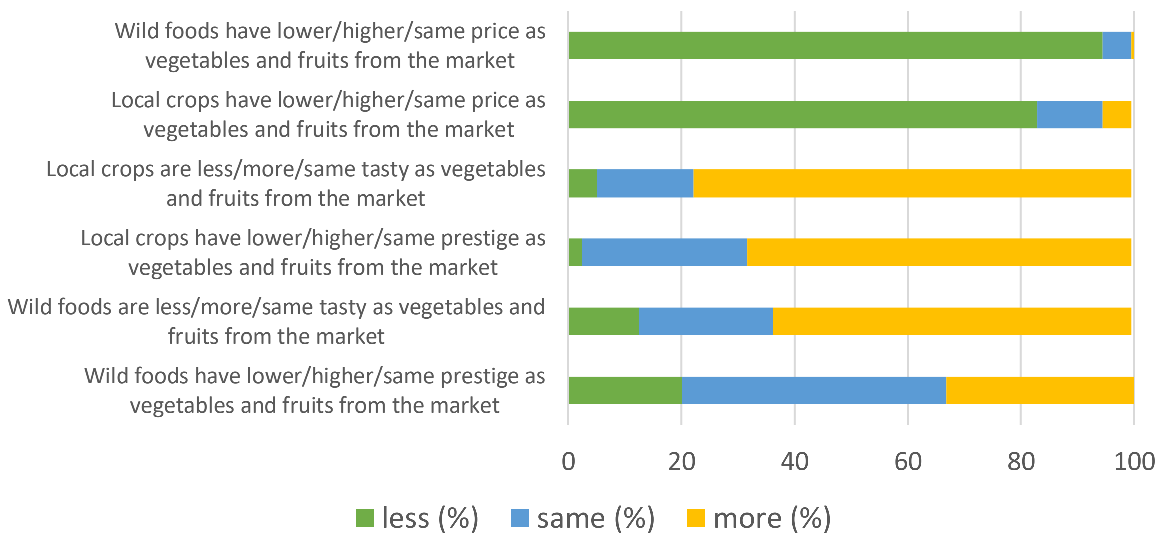


Figure 24 Perception of women on local and marketed foods

Traditional knowledge and uses of wild food plants are generally decreasing worldwide. Since most of the studies have looked at the reasons for the decline in use, we wanted to understand also the motivations for their continued use. Therefore, we let women list specific reasons for continuing their consumption. What we found is that the most prevalent motivations were that wild food plants are obtained for free or at a low cost (45%); that they are natural food unpolluted by agricultural chemicals (44%); and that some are still available and easy to obtain (32%) (Fig. 25). While the economic factor (available for free) was of parallel importance for both ethnic groups, the importance of being an unpolluted natural food was more prevalent among Minangkabau women, while availability was listed more by Mandailing women.

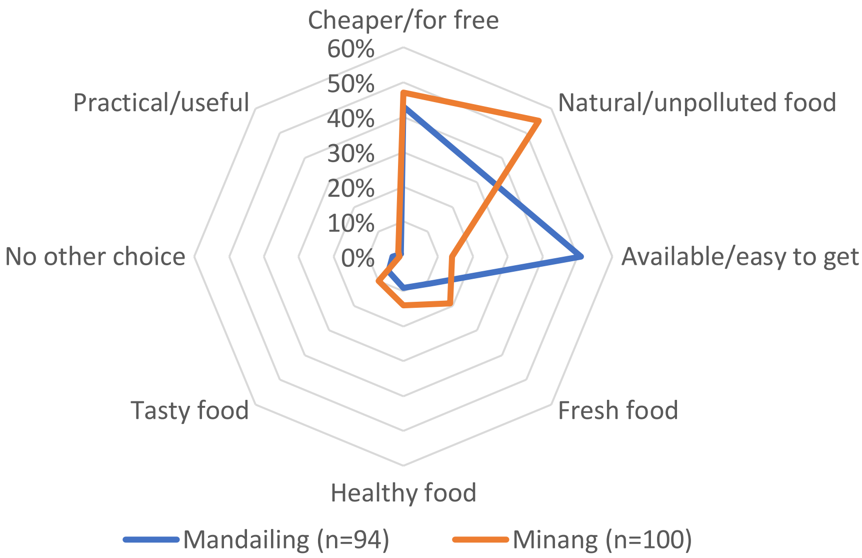


Figure 25 Motivations for continued consumption of wild food plants (% of respondents)

Although we tried to enrich these perceptions of local foods by positive and negative personal stories through narrative-based documentation, the majority of respondents were not able to recall any story related to local food plants. Thus, we did not conduct a full analysis of the narratives. Nevertheless, a few examples of collected stories can give a broader picture of the local food environment:

A personal story from Mandailing woman Ms Karmila: "*When I was picking water spinach in my rice field, suddenly I am holding a snake, I was shocked and ran away!*"

Minangkabau Ms Roslaini shared: "*When walking in the garden, I was pleased to see many durian fruits falling down, later when I came to pick them, it turned out that tigers had already eaten the durians*".

These examples illustrate personal experiences and situations that communities occasionally face in the rural areas of West Sumatra during agriculture activities or collecting wild foods. Farmers often encounter wildlife, or some other stories often mentioned slipping and falling down in the field or from a motorbike on the way to the fields or uphill cocoa gardens.

6.2.4 Trends and changes in the use of food plants

Through the 4-cell method conducted during FGDs (Fig. 26), the study revealed the perceived drivers of changes in production, collection, and consumption of local food plants. The drivers of change in diversity and species utilization were categorized into different themes through inductive thematic analysis. In addition, we sought out which factors are determining whether a species is utilized or underutilized. In general, the results showed that the use of local fruits and vegetables has declined over the last generation.

Figure 26 Participatory 4-cell method assessing the changes in diversity and use of local food plants (Sontang village, May 2018)

The reasons for the changes compared to the past, as well as the barriers and motivations for contemporary use of food plants were categorized into the following six emerged themes: (i) availability; (ii) livelihood and lifestyle; (iii) food, consumption, health; (iv) income, marketing, economy; (v) multifunctionality/processing; and (vi) knowledge and skills.

Thematically categorized authentic motivations and barriers to the current use of cultivated vegetables, along with reasons for their greater use in the past, are given in Tab. 16, for cultivated fruits in Tab. 17, wild vegetables in Tab. 18 and wild fruits in Tab. 19.

Table 16 Barriers, motivations and reasons for changes in the use of cultivated vegetables

Ethnic group	Reasons for cultivating selected vegetables on large areas currently (FUS)[1]	Reasons for cultivating selected vegetables on small areas currently (NUS)[1]	Reasons for cultivating a higher diversity of vegetables in the past
Minangkabau	Basic food needed daily (F) They grow and thrive easily (P) Many benefits (U) Easy marketing (I) Easy to get (A) Can be marketed (I) Liked by people (F) Nutrition a lot (F) harvest quickly (A) Does not need much land (L)	Not enough land (L) Less popular (F) Lack of knowledge on their cultivation (K) Narrow land (L) Can be bought (D) Seeds are hard to get (A)	Persistence of women in growing vegetables (D) People needed vegetables (F) Many benefits (U) Good for selling (I) Local vegetables were popular (F) People were often going to the forest (D) Easy to plant (P) Do not disturb other crops (P) Everyone was gardening (D) Everyone liked them (F) These were common (A) Good land availability (L)
Mandailing	Easy to plant (A) Needed food, consumed regularly (F) Liked much (F) Can be marketed (I) Save location (L) Easy to grow (P) Easy for processing (S) Can be grown in the rainy season (A) No other vegetables (A) Lots of nutrition (F)	Marketing is difficult (I) Not enough land (L) Difficult to care for (A) Not many gardeners (D) Costs a lot (biaya banyak) (I) Not in demand (I) Require specific land (L)	Many people like them (F) Good land availability (L) Healthy food without chemicals (F) Field without chemicals (P) Vegetables available to some extent (A) There are interested farmers (D) Many benefits (U) Likes to intercrop (P)

[1] FUS = Fully utilized species, NUS = Neglected and underutilized species
A = Availability; D = Demography/lifestyle; F = Food, consumption, health; I = Income, marketing, economy; K = Knowledge gap; L = Land issue; P = Agriculture production; S = Processing/storage; U = Usefulness

Table 17 Barriers, motivations and reasons for changes in the use of cultivated fruits

Ethnic group	Reasons for cultivating selected fruits on large areas currently (FUS)[1]	Reasons for cultivating selected fruits on small areas currently (NUS)[1]	Reasons for cultivating a higher diversity of fruits in the past

Minangkabau	They are tasty (F) Easy to grow (P) Can be sold (I) Grow easily (P) Provide daily needs (F) Can be processed in various ways (S) Own production (D) Many devotees (D) Preferred fruits (F)	Need a large space (L) Seasonal (P) Own (D) Hard to find (A) Depends on the land (L) Devotees are decreasing (D) Can be sold (I) Don't know how to cultivate (K)	People liked taste (F) Easy to grow (P) Could be sold (I) Own production (D) Producing seasonally (P) Homegardens were larger (L) Provided daily needs (F) Many people interested (D) There was a lot of land (L)
Mandailing	Easy to plant (P) Good to consume (F) Not difficult to grow (P) Because it's in the fields (A) Daily needs (F) Easy marketing (I) Available in large quantities (A)	Limited land (L) Devotees are decreasing (D) No time (D) Hard to get them (A) Almost extinct (A) Cultivation is difficult (P)	There was a lot of fruits (A) More land was available (L) Women were diligently planting them (D) Easy to get (A) People liked the taste (F) Rare in the market (A) Could be sold (I)

[1] FUS = Fully utilized species, NUS = Neglected and underutilized species
A = Availability; D = Demography/lifestyle; F = Food, consumption, health; I = Income, marketing, economy; K = Knowledge gap; L = Land issue; P = Agriculture production; S = Processing/storage; U = Usefulness

Table 18 Barriers, motivations and reasons for changes in the use of wild vegetables

Ethnic group	Reasons for collecting selected wild vegetables to a large extent currently (FUS)[1]	Reasons for collecting selected wild vegetables to a small extent currently (NUS)[1]	Reasons for collecting wild vegetable more in the past
Minangkabau	People like them (F) These are required (F) Can be obtained in the forest (A) No need to purchase (I) Good economic value (I) Can be shared (A) Good benefits (U) Many enthusiasts (D) Land area (L) There are no other vegetables (A) Source of income (I)	Reduced interest (D) Limited land (L) Competitiveness (A) Not available in the market (A) Don't know the taste (K) Don't know yet can be consumed (K) Hard to get (A) Dislike (F) Need good care (P)	Easy to get (A) Easy to grow (P) Are for free (A) Community collection (D) Still plenty of them (A) People were gardening (D) People liked them (F) There were no other vegetables (A) Spacious gardens (L) Easy processing (S) Abundant forests (A)
Mandailing	Easy to get (A) Eaten every day (F) Rich in nutrients (F) People like them (F) At close range (A) Not purchased (I) Good taste (F) Many enthusiasts (D) Many benefits (U)	Competition (A) Taste is not so good (F) Not consumed much (F) Not much available (A) Don't know how to cook (K) Not all like it (D) Hard to get it (A)	Easy to get (A) Food needed every day (F) Healthy (F) People were often going to the forest (D) There was more forest (L) Many enthusiasts (D) Collect their own (A) Traditional processing (S) No other vegetables (A) Are for free (I)

[1] FUS = Fully utilized species, NUS = Neglected and underutilized species
A = Availability; D = Demography/lifestyle; F = Food, consumption, health; I = Income, marketing, economy; K = Knowledge gap; L = Land issue; P = Agriculture production; S = Processing/storage; U = Usefulness

Table 19 Barriers, motivations and reasons for changes in the use of wild fruits

Ethnic group	Reasons for collecting selected wild fruits to a large extent currently (FUS)[1]	Reasons for collecting selected wild fruits to a small extent currently (NUS)[1]	Reasons for collecting wild fruits more in the past
Minangkabau	They are tasty (F) There are no other fruits (A) Can be collected on your own (A) Eaten every day (F) Can be sold (I) Can be processed according to taste (S) They are required (F) Many enthusiasts (D)	Don't know how to cultivate them (K) Not a big interest (D) Rare (A) Grow in the forest (A) Available seasonally (A) Depends on the land (L) Not so tasty (F) People don't know it (K) Hard to get (A) Used for medicine (U)	They are tasty (F) Easy to grow (P) Can be sold (I) There are no other fruits (A) Seasonal (A) People often go to the forest (D) Only a few options (A) Many fruits available (A) Cheap to purchase (I)
Mandailing	Easy to collect (A) Available in large quantities (A) Still plentiful (A) No need to buy (I) Many people like it (F) There are no other fruits (A) Kids like them (F)	Not enough time (D) Extinct or rare (A) Decreasing as a result of spraying (A) Hard to get (A) Difficult to cultivate them (P) They are seasonal (A) Not in the market (A) People are busy (D)	Easy to get (A) People did not spray chemicals (A) Land was available (L) People liked taste (F) Cheap to purchase (I) Many were available (A) No other fruits (A) Natural and healthy (F) No need to buy (I) Many in the season (A)

[1] FUS = Fully utilized species, NUS = Neglected and underutilized species
A = Availability; D = Demography/lifestyle; F = Food, consumption, health; I = Income, marketing, economy; K = Knowledge gap; L = Land issue; P = Agriculture production; S = Processing/storage; U = Usefulness

The tables above with authentic explanations demonstrate that reduced availability of local food plants was the most prevalent explanation for their decreased use compared to the past. This is followed by changes in livelihood and lifestyle and after that, factors related to the food environment, consumption and health.

The most common current barriers for not using local food plants were their reduced availability, but also limited food composition knowledge, time constraints, and lower economic value. These findings represent the community perspective, and it informs us what factors are driving underutilization of even loss of food biodiversity.

But there are differences in the extent of use of different species. Some species are better utilized mainly for the following reasons: being important and tasty food; easy management and growth; good availability and accessibility; having multiple benefits; and providing marketing opportunity.

6.2.5 Quantifying contribution and potential of food biodiversity to dietary diversity

First, we calculated the gap between the knowledge on available food biodiversity and the actual consumption in the last 24 hours (Tab. 20). It was found that Pulses had the highest utilization ratio, as 78% of available species were consumed. On the other hand, the largest gap was identified for Nuts and seeds where out of 6 available species, only 1 species was consumed in the last 24 hours (17%). The overall utilization ratio regardless of the particular food group was 55%, meaning that 45% of available food plant species were not consumed in the last 24 hours.

Table 20 The gap between food biodiversity and actual food consumption

Food group	Proportion of consumers in the last 24 hours (%)[1]	Number of species consumed in the last 24 hours	Total number of species available in the food systems	The species gap and utilization ratio between consumed and available foods
Starchy staples	100	6	8	2 (75% used)
Leafy vegetables	62	15	28	13 (54 % used)
Other vegetables	62	29	42	13 (69 % used)
Pulses	48	7	9	2 (78 % used)
Nuts and seeds	8	1	6	5 (17 % used)
Vit. A-rich plants	6	4	10	6 (40 % used)
Other fruits	40	16	50	34 (32% used)
Total	**N/A**	**65**	**131**	**66 (55% used)**

[1] in food recall 2, which had higher food and dietary diversity

The newly proposed indices for quantification of the species' contribution to diets is based on the data obtained through 24-h food recalls. The Species' Contribution to Diets (CDs) index identified the most consumed edible species. Then Species' Underutilization in Diets (UDs) index identified the most underutilized species. And lastly, the Species' Potential for Diets (PDs) index identified species with the highest potential for diversifying diets. The species which are a source of food from more than one food group showed to have higher potential for dietary diversity. The indices are complementary, and the full interpretation is achieved when all three indicators are considered. For example, while rice in the study area obtained the highest CD index (1), the complementary PD index explained that the species has not a high potential (1) and UD index of 0 added that this species is fully utilized, and there is no more opportunity to use this species for diversifying diets (Tab. 21). Papaya plant, on the other hand, is despite a very high potential (PD = 3) contributing minimally to dietary diversity of the women (CD = 0.05). However, the papaya plant offers a vast potential to diversify the diets (UD = 2.95). The indices are based on food intake data limited to one point in time (last 24 hours). Therefore, the limitation is that it does not represent the overall situation across different seasons over the year. This may underestimate edible species that are not harvestable during the study period.

Table 21 Species´ potential, contribution and underutilization for diets in descending order of species contribution to diets (CD index; food recall 2; n=200)

Common name	Latin name	Food group	NFG	FR_{max}	FR_{actual}	FR_{missed}	PD	CD	UD
Rice	*Oryza sativa*	staples	1	200	200	0	1	1	0
Soy bean	*Glycine max*	pulses	1	200	91	109	1	0.455	0.545
Cassava (species)	*Manihot esculenta*	2 food groups	2	400	82	318	2	0.41	1.59
Chicken (species)	*Gallus gallus domesticus*	2 food groups	2	400	76	324	2	0.38	1.62
Wheat	*Triticum aestivum*	staples	1	200	76	124	1	0.38	0.62
Cassava leaf	*Manihot esculenta*	leafy vegetables	1	200	71	129	1	0.355	0.645
Banana (species)	*Musa* x *paradisiaca*	2 food groups	2	400	67	333	2	0.335	1.665
Banana (fruit)	*Musa* x *paradisiaca*	Other fruits	1	200	64	136	1	0.32	0.68
Chicken egg	*Gallus gallus domesticus*	eggs	1	200	49	151	1	0.245	0.755
Potato	*Solanum tuberosum*	staples	1	200	44	156	1	0.22	0.78
Eggplant	*Solanum melongena*	other vegetables	1	200	40	160	1	0.2	0.8
Chicken meat	*Gallus gallus domesticus*	meat	1	200	27	173	1	0.135	0.865
Leafy amaranth	*Amaranthus hybridus*	leafy vegetables	1	200	23	177	1	0.115	0.885
Long bean	*Vigna unguiculata* ssp. *sesquipedalis*	other vegetables	1	200	23	177	1	0.115	0.885
Coconut	*Cocos nucifera*	Other fruits	1	200	22	178	1	0.11	0.89
Anchovy	*Engraulidae* family	meat	1	200	21	179	1	0.105	0.895
Common bean	*Phaseolus vulgaris*	other vegetables	1	200	21	179	1	0.105	0.895
Jackfruit (species)	*Artocarpus heterophyllus*	2 food groups	2	400	19	381	2	0.095	1.905
Cow meat	*Bos taurus*	meat	1	200	19	181	1	0.095	0.905
Turkey berry	*Solanum rudepannum*	other vegetables	1	200	19	181	1	0.095	0.905

Jackfruit (unripe fruit)	*Artocarpus heterophyllus*	other vegetables	1	200	18	182	1	0.09	0.91
Carp	*Cyprinus carpio*	meat	1	200	15	185	1	0.075	0.925
Catfish	*Clarias* sp.	meat	1	200	15	185	1	0.075	0.925
Peanut	*Arachis hypogaea*	nuts and seeds	1	200	13	187	1	0.065	0.935
Leafy mustard	*Brassica rapa*	leafy vegetables	1	200	13	187	1	0.065	0.935
Cassava (tuber)	*Manihot esculenta*	staples	1	200	11	189	1	0.055	0.945
Maize	*Zea mays*	other vegetables	1	200	11	189	1	0.055	0.945
Papaya (species)	*Carica papaya*	3 food groups	3	600	10	590	3	0.05	2.95
Cucumber	*Cucumis sativus*	other vegetables	1	200	10	190	1	0.05	0.95
Pumpkin (species)	*Cucurbita moschata*	2 food groups	2	400	9	391	2	0.045	1.955
Durian	*Durio zibethinus*	Other fruits	1	200	9	191	1	0.045	0.955
Chayotte (species)	*Sechium edule*	2 food groups	2	400	9	391	2	0.045	1.955
Vegetable fern	*Diplazium esculentum*	leafy vegetables	1	200	8	192	1	0.04	0.96
Duck meat	*Anas platyrhynchos domesticus*	meat	1	200	8	192	1	0.04	0.96
Water spinach	*Ipomoea aquatica*	leafy vegetables	1	200	8	192	1	0.04	0.96
Chayotte (fruit)	*Sechium edule*	other vegetables	1	200	8	192	1	0.04	0.96
Jengkol	*Archidendron pauciflorum*	pulses	1	200	7	193	1	0.035	0.965
Bitter gourd	*Momordica charantia*	other vegetables	1	200	7	193	1	0.035	0.965
Mung bean	*Vigna radiata*	pulses	1	200	7	193	1	0.035	0.965
Pumpkin leaf	*Cucurbita moschata*	leafy vegetables	1	200	6	194	1	0.03	0.97
Carrot	*Daucus carota*	vitamin A rich plant	1	200	6	194	1	0.03	0.97
Sweet leaf	*Sauropus androgynus*	leafy vegetables	1	200	6	194	1	0.03	0.97
Cabbage	*Brassica oleracea* var. *capitata*	other vegetables	1	200	5	195	1	0.025	0.975
Papaya leaf	*Carica papaya*	leafy vegetables	1	200	5	195	1	0.025	0.975
Tomato	*Lycopersicum esculentum*	other vegetables	1	200	5	195	1	0.025	0.975
Yellowcress	*Rorripa indica*	leafy vegetables	1	200	5	195	1	0.025	0.975

Papaya (ripe fruit)	*Carica papaya*	vitamin A rich plant	1	200	4	196	1	0.02	0.98
Langsat	*Lansium parasiticum*	Other fruits	1	200	4	196	1	0.02	0.98
Ridge gourd	*Luffa acutangula*	other vegetables	1	200	4	196	1	0.02	0.98
Bamboo shoot	*Bambusa vulgaris*	other vegetables	1	200	3	197	1	0.015	0.985
Orange	*Citrus sinensis*	Other fruits	1	200	3	197	1	0.015	0.985
Pumpkin	*Cucurbita moschata*	vitamin A rich plant	1	200	3	197	1	0.015	0.985
Eel fish	*Monopterus albus*	meat	1	200	3	197	1	0.015	0.985
Sweet potato	*Ipomoea batatas*	staples	1	200	3	197	1	0.015	0.985
Banana flower	*Musa* x *paradisiaca*	other vegetables	1	200	3	197	1	0.015	0.985
Avocado	*Persea americana*	Other fruits	1	200	3	197	1	0.015	0.985
Winged bean	*Psophocarpus tetragonolobus*	other vegetables	1	200	3	197	1	0.015	0.985
Quail	*Coturmix* sp.	meat	1	200	3	197	1	0.015	0.985
Snake fruit	*Sallaca zalaca*	Other fruits	1	200	3	197	1	0.015	0.985
Bilimbi	*Averrhoa bilimbi*	other vegetables	1	200	2	198	1	0.01	0.99
Cowpea	*Cajanus cajan*	pulses	1	200	2	198	1	0.01	0.99
Watermelon	*Citrullus lanatus*	Other fruits	1	200	2	198	1	0.01	0.99
Black nightshade	*Solanum americanum*	leafy vegetables	1	200	2	198	1	0.01	0.99
Pineapple	*Ananas commosus*	Other fruits	1	200	1	199	1	0.005	0.995
Kabau	*Archidendron bubalinum*	pulses	1	200	1	199	1	0.005	0.995
Jackfruit (ripe fruit)	*Artocarpus heterophyllus*	Other fruits	1	200	1	199	1	0.005	0.995
Catfish	*Bagrus nemurus*	meat	1	200	1	199	1	0.005	0.995
Cauliflower	*Brassica oleracea* var. *botrytis*	other vegetables	1	200	1	199	1	0.005	0.995
Papaya (unripe fruit)	*Carica papaya*	other vegetables	1	200	1	199	1	0.005	0.995
Torch ginger	*Etlingera elatior*	other vegetables	1	200	1	199	1	0.005	0.995
Giant Gourami	*Osphronemus goramy*	meat	1	200	1	199	1	0.005	0.995
Genjer	*Limnocharis flava*	leafy vegetables	1	200	1	199	1	0.005	0.995
Sapodilla	*Manilkara zapota*	Other fruits	1	200	1	199	1	0.005	0.995

Jicama	*Pachyrhizus erosus*	other vegetables	1	200	1	199	1	0.005	0.995
Stink bean	*Parkia speciosa*	pulses	1	200	1	199	1	0.005	0.995
Date	*Phoenix dactylifera*	Other fruits	1	200	1	199	1	0.005	0.995
Oyster mushroom	*Pleurotus ostreatus*	other vegetables	1	200	1	199	1	0.005	0.995
Guava	*Psidium guajava*	Other fruits	1	200	1	199	1	0.005	0.995
Pear	*Pyrus* sp.	Other fruits	1	200	1	199	1	0.005	0.995
Chayotte (leaf)	*Sechium edule*	leafy vegetables	1	200	1	199	1	0.005	0.995
Mung bean sprouts	*Vigna radiata*	other vegetables	1	200	1	199	1	0.005	0.995
Mung bean (species)	*Vigna radiata*	2 food groups	2	400	1	399	2	0.005	1.995

NFG = Number of Food Groups
Fr_{max} = The theoretical maximum number of food reports for the species S in the food groups FG
Fr_{actual} = Actual number of food reports for the species S in the food groups FG (FG1…FG10)
Fr_{missed} = Is the difference between the theoretical maximal number of food reports and the actual number of food reports for the species S
PD = Species' Potential for Diets
CD = Species' Contribution to Diets
UD = Species' Underutilization in Diets

The new indices can be used and visualized in various ways. The new analysis discovered that certain species are in fact "multi-food group species" as their different plant parts (or fruit maturity) feeds into nutritionally different food groups by FAO & FHI360 (2016). Fig. 27 shows the contribution of multi-food group species to dietary diversity according to CD index in particular food groups. We can observe that among these species, cassava plant is the greatest contributor to dietary diversity of the community (more as a leafy vegetable and less as a starchy staple). A few species such as papaya plant is a remarkably diverse and potential food source, providing three food groups in the study area (Leafy vegetables, Other vegetables, Vitamin A-rich plants).

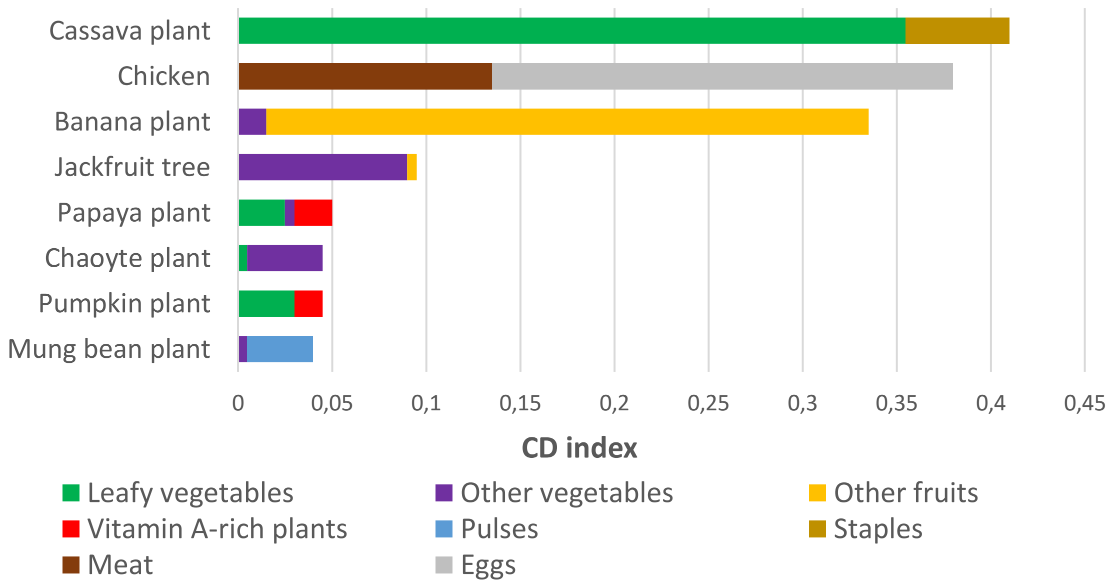


Figure 27 Multi-food group species and their contribution to diets of women in West Sumatra based on CD index

6.2.6 Identification of nutrient-rich local foods

In the previous chapter 6.2.5, promising species which have a high potential to diversify the diets were identified through newly developed quantitative indices. Besides, using a food groups approach, all items in the nutritious food groups of Leafy Vegetables, Pulses, Vitamin A-rich plants, can be considered nutrient-rich foods (animal-based food groups too). The full list of biodiversity in these food groups can be seen in the annexed Tab. A1 (Appendix 1). Nevertheless, this food group generalization may, in reality, both over-estimate or under-estimate true nutritional content and potential of certain foods. It also does not address the more concrete nutritional needs of the given population. Therefore, we further reviewed Indonesian and additional food composition tables and identified local foods rich in the under-consumed nutrients (iron, folate, vitamin A, calcium, with the addition of protein). This information was communicated in the community book produced by the study. Although the study focused on the plants (the community guidebook included detailed monographs of 100 food plants), the list of nutrient-dense animal-based foods were also included in the book sections on how to tackle diet-related health problems. In the review, however, the diversity of aquatic resources was not exhaustive as the study did not identify all local fish species, and edible fish biodiversity is highly under-represented in Indonesian food composition tables. The food composition values given in the following tables (Tab. 22-26) are based on the review of food composition tables (MOH 2018b; INMU 2014; Berger et al. 2013). Several processed sugar-rich food products such as biscuits and instant beverages were found to have high micronutrient content (iron, folate, vitamin A, calcium) due to their fortification. They were kept in the tables for their actual nutrient content, but due to their overall unhealthy profile, their increased consumption was not recommended by the study and in the community materials.

Tab. 22 shows the richest sources of protein that are locally available. In the community book, protein-rich foods were positioned as suitable to reduce stunting and poor growth. In the table, we can see that although a few plant-based foods such as pulses are rich in protein, the majority of protein-rich foods are animal-based. Based on the food intake analysis, 79% of women reached RDA of protein. But according to the governmental data, the region still suffers from a high prevalence of stunting (MOH 2018a). This is caused not only by poor diets but by multiple factors including poverty, hygiene and sanitation. In case of diets in the study area, protein intake came mainly from fish, soy bean (tempeh and tofu), and to a lower extent from chicken and eggs. Overall, the consumed portion sizes of protein-rich foods were small.

Table 22 List of available protein-rich foods (selection of 30 foods with the highest content)

English name	Indonesian name	Food type	Protein content (grams per 100g)
Broad bean	Kacang babi (dried)	Plant-based	30.4
Chicken heart	Ayam hati	Animal-based	27.4
Peanut	Kacang tanah	Plant-based	26.9
Quail	Burung puyuh	Animal-based	25
Cowpea seeds	Kacang tunggak (dried)	Plant-based	24.4
Deer	Rusa	Animal-based	23
Mung bean seeds	Kacang hijau (dried)	Plant-based	22.9
Red beans	Kacang merah	Plant-based	22.1
Tilapia	Ikan nila	Animal-based	21.4
Shrimp	Udang segar	Animal-based	21
Sardine	Ikan dencis	Animal-based	19.9
Beef	Daging sapi	Animal-based	19.1
Mozambique tilapia	Ikan mujair	Animal-based	18.7
Chicken	Ayam	Animal-based	18.2
Goat	Kambing	Animal-based	16.6
Snakehead	Ikan gabus	Animal-based	16.2
Squid	Cumi-cumi	Animal-based	16.1
Carp	Ikan mas	Animal-based	16
Duck	Itik/Bebek	Animal-based	16
Catfish	Ikan baung	Animal-based	15.1
Beltfish	Ikan belida	Animal-based	14.7
Swamp eel	Ikan belut	Animal-based	14.6
Tempeh (soy bean)	Tempeh	Plant-based	14
River snail	Langkitang	Animal-based	12
Tofu (soy bean)	Tahu	Plant-based	10.9
Duck egg	Telur bebek	Animal-based	10.9
Chicken egg	Telur ayam kampung	Animal-based	10.8
Quail egg	Telur puyuh	Animal-based	10.7
Anchovies	Ikan teri (raw)	Animal-based	10.3
Pangi	Kluwek	Plant-based	10

Tab. 23 shows the richest local sources of iron. Iron-rich foods were in the community book recommended as being capable of tackling anaemia. The richest sources of iron are equally both plant and animal-based. Nonetheless, it must be noted that animal-based sources provide haem iron which is more bioavailable compared to non-haem iron occurring in plants (Kennedy et al. 2007). Based on food intake analysis, only 16% of women reached RDA of iron. The iron-rich animal-based foods are consumed rarely and often in small amounts due to economic affordability. While leafy vegetables are common, they are consumed in low amounts and in low species diversity (the predominantly consumed are the popular cassava leaves "pucuk ubi").

Table 23 List of available iron-rich foods (selection of 30 foods with the highest content)

English name	Indonesian name	Food type	Iron content (mg per 100g)
Chocolate biscuit	Biskuit coklat	Plant-based	19.8 (fortified)
Chicken heart	Ayam hati	Animal-based	15.8
Beef meat (rendang)	Rendang sapi	Animal-based	14.9
Shrimp	Udang segar	Animal-based	8.0
River snail	Langkitang	Animal-based	7.9
Mung bean seeds	Kacang hijau	Plant-based	7.5
Cassava leaf (red)	Daun ubi merah	Plant-based	6.4
Sticky rice	Beras ketan	Plant-based	6.2
Moringa leaf	Daun kelor	Plant-based	6.0
Chicken meat	Ayam goreng	Animal-based	5.4
Duck egg	Telur itik/bebek	Animal-based	5.4
Local chicken egg	Telur ayam kampung	Animal-based	4.9
Vegetable fern	Daun pakis rebus	Plant-based	4.8
Pigeon pea seeds	Kacang gude	Plant-based	4.7
Biscuit Roma	Biskuit roma	Plant-based	4.7 (fortified)
Instant coffee Kapal Api	Kopi instan kapal api	Sweet beverage	4.4 (fortified)
Quail meat	Burung puyuh	Animal-based	4.4
Snake fruit	Salak	Plant-based	4.2
Peanut	Kacang tanah	Plant-based	4.1
Tofu (soy bean)	Tahu goreng	Plant-based	4.1
Tempeh (soy bean)	Tempeh	Plant-based	4.0
Milo instant drink	Milo bubuk	Sweet beverage	4.0 (fortified)
Instant noodles	Mie instan	Plant-based	4.0 (fortified)
Biscuit Nabati	Wafer nabati	Plant-based	3.7 (fortified)
Pumpkin leaf	Daun labu	Plant-based	3.7
Common bean (red)	Kacang merah	Plant-based	3.7
Anchovies (dried)	Ikan teri, kering	Animal-based	3.6
Leafy amaranth	Bayam segar	Plant-based	3.5
Sweet leaf	Daun katuk	Plant-based	3.5
Sardines	Ikan dencis	Animal-based	3.5

Tab. 24 shows the richest local sources of folate. As folate is crucial during pregnancy for foetus development, in the community book, pregnant women were encouraged to consume more of folate-rich foods. Looking at the table, it is evident that plant-based foods are the more excellent sources of folate than animal-based foods. Some of the remarkably rich sources are pulses, which unfortunately, were highly under-consumed. Based on nutrient intake analysis, only 4% of women were found to reach RDA of folate. This is extremely low, caused by almost non-existent consumption of pulses and a limited amount of consumed vegetables. Here, particularly the potential of leafy vegetables should be leveraged.

Table 24 List of available folate-rich foods (selection of 30 foods with the highest content)

English name	Indonesian name	Food type	Folate content (mg per 100g)
Pigeon pea seeds	Kacang gude, biji	Plant-based	456.0
Common bean (red)	Kacang merah	Plant-based	343.0
Instant drink Energen	Energen rasa coklat	Sweet beverage	275.9 (fortified)
Mung bean seeds	Kacang hijau	Plant-based	208.0
Leafy amaranth (red)	Bayam merah	Plant-based	194.0
Biscuit Nissin Crispy	Biskuit nissin crispy	Plant-based	152.0 (fortified)
Peanut	Kacang tanah sangan	Plant-based	145.5
Instant noodles	Mie instan indomie	Plant-based	145.0 (fortified)
Nightshade leaf	Daun leunca, segar	Plant-based	130.5
Snack Ringgo	Snack ringgo Rp. 1000	Plant-based	118.1 (fortified)
Chocolate bread	Sari roti coklat sobek	Plant-based	108.0 (fortified)
Broccoli	Brokoli rebus	Plant-based	108.0
Local chicken egg	Telur ayam kampung	Animal-based	98.7
Stinky bean	Petai, segar	Plant-based	92.0
Chicken meat	Ayam negeri goreng	Animal-based	86.0
Bread (wheat)	Roti tawar	Plant-based	85.8 (fortified)
Avocado	Alpukat	Plant-based	81.0
Duck egg	Telur itik/bebek mentah	Animal-based	80.0
Mung bean sprouts	Toge rebus	Plant-based	80.0
Waffle biscuit Nabati	Wafer nabati keju	Plant-based	77.0 (fortified)
Potato cracker	Kripik kentang chitato	Plant-based	75.0
French bean	Buncis, segar	Plant-based	74.2
Leafy mustard	Sawi	Plant-based	73.0
Biscuit Marie Roma	Biskuit marie roma	Plant-based	70.9 (fortified)
Chicken egg	Telur ayam ras, segar	Animal-based	69.0
Shallot leaf	Daun bawang merah	Plant-based	64.0
Cake Bika Ambon	Bika ambon	Animal-based	63.0
Lontong (rice cake)	Lontong	Plant-based	61.1
Cassava tuber	Ketela pohon/singkong	Plant-based	53.0

Tab. 25 shows foods with the highest content of vitamin A (RAE). In the guidebook, vitamin A-rich foods were highlighted as crucial for human sight. Both plant and animal sources are good sources of it. From plants, there are orange-fleshed vegetables and also dark green leafy vegetables available. The chicken heart is by far the most abundant source (note that livers are not listed, as livers were not found to be consumed locally). Only 12% of women reached RDA of vitamin A. The low intake of vitamin A is associated with small portions of meat and with limited consumption of vitamin A-rich fruits and vegetables. Vitamin A-rich fruit trees such as mango or papaya are widespread but consumed only seasonally or occasionally. Vitamin A-rich vegetables are consumed slightly more frequently but in small amounts.

Table 25 List of available vit. A-rich foods (selection of 30 foods with the highest content)

English name	Indonesian name	Food type	Vit. A content (RAE per 100g)
Chicken heart	Ayam, hati, segar	Animal-based	6127.7
Mango	Mangga gedong/gadung	Plant-based	723.3
Cassava snack	Sarang balam	Plant-based	709.0
Sweet potato	Ubi jalar manis, segar	Plant-based	698.9
Butter	Mentega	Animal-based	671.0
Carrot	Wortel mentah	Plant-based	478.0
Leafy amaranth (red)	Bayam merah	Plant-based	469.0
Caviplex supplement	Caviplex (supplement)	Supplement	416.7
Lettuce	Selada, segar	Plant-based	370.0
Moringa leaf	Daun kelor, segar	Plant-based	362.8
Leafy mustard	Sawi	Plant-based	316.0
Duck	Bebek (itik)	Animal-based	275.6
Cake Bika Ambon	Bika ambon	Plant-based	260.0
Instant drink Energen	Energen rasa coklat	Sweet beverage	258.0 (fortified)
Local chicken egg	Telur ayam kampung	Animal-based	257.5
Chicken meat	Ayam, daging, segar	Animal-based	246.6
Pak choi	Sawi putih/ pecai	Plant-based	212.0
Instant drink Milo	Milo (bubuk)	Sweet beverage	210.0 (fortified)
Duck egg	Telur itik/bebek mentah	Animal-based	197.1
Mackerel tuna	Ikan tongkol, segar	Animal-based	181.8
Cassava leaf	Daun ubi merah, kukus	Plant-based	179.6
Chicken egg	Telur ayam ras, segar	Animal-based	149.0
Quail egg	Telur burung puyuh	Animal-based	142.3
Sardines	Ikan sarden, segar	Animal-based	119.0
Pumpkin	Labu kuning (waluh)	Plant-based	100.0
Sea fish (Rastrelliger sp.)	Ikan oci/Kembung	Animal-based	90.6
Nightshade leaf	Daun leunca, segar	Plant-based	88.7
Sardines	Ikan dencis	Animal-based	77.2
Broccoli	Brokoli	Plant-based	77.0

Tab. 26 presents local foods with the highest content of calcium. Both plant and animal sources can be good sources of calcium. The richest are animal-based anchovies, shrimp, and beef, followed by processed and mostly fortified foods such as cakes, biscuits and instant beverages. Only 10% of women reached RDA of calcium. Although communities consume dried or fresh fish basically on a daily basis, the portion size of fish is usually very small, not providing enough calcium and other nutrients.

Table 26 Local sources of calcium-rich foods (selection of 30 foods with the highest content)

English name	Indonesian name	Food type	Calcium content (mg per 100g)
Anchovies (dried)	Ikan teri, kering	Animal-based	1200.0
Shrimp	Udang rebon, segar	Animal-based	757.0
Cake bolu	Bolu keju	Plant-based	595.0
Beef rendang	Rendang sapi, masakan	Animal-based	474.0
Biscuit Original	Biskuit biskuat original	Plant-based	416.7
Instant drink Energen	Energen rasa coklat	Sweet beverage	413.8
Instant drink Milo	Milo (bubuk)	Sweet beverage	385.0
Chocolate milk	Susu uht indomilk coklat	Animal-based	382.6
Sardines	Sardines dalam kaleng	Animal-based	354.0
Papaya leaf	Daun pepaya, segar	Plant-based	353.0
Belida fish	Ikan Belida, segar	Animal-based	303.0
Common bean (red)	Kacang merah	Plant-based	293.0
Gurame fish	Gurame asem manis	Animal-based	283.0
Tilapia fish	Nile tilapia (fried)	Animal-based	264.0
Noodles with chicken	Mie ayam	Plant-based	262.0
Sweet leaf	Daun katuk, segar	Plant-based	233.0
Cake klepon	Klepon (rice cake)	Plant-based	232.0
Tofu	Tahu	Plant-based	223.0
Mung bean	Kacang hijau	Plant-based	223.0
Tofu cracker	Kerupuk tahu	Plant-based	223.0
Leafy mustard	Sawi	Plant-based	220.0
Papaya flower	Bunga pepaya	Plant-based	220.0
Salty dried fish	Ikan asin, kering	Animal-based	200.0
Biscuit Roma Kelapa	Biskuit roma kelapa	Plant-based	190.9
Cassava cracker	Keripik singkong	Plant-based	189.0
Instant coffee	Kopi bubuk instant	Sweet beverage	179.0
Snakehead	Ikan gabus, segar	Animal-based	170.0
Leafy amaranth	Bayam, segar	Plant-based	166.6
Cassava leaf	Daun singkong rebus	Plant-based	160.0

7. Discussion

7.1 Diets and factors that predict them

This doctoral study generated a detailed dietary assessment of rural women from farming households living in a biodiverse tropical environment of West Sumatra. The study paid attention to the thorough identification of foods consumed and matching the best food composition values to minimize the errors, which tend to be high in dietary intake studies due to limited biodiversity knowledge of nutritionists and limited food composition data. In our study, the dietary assessment used three dietary indicators: a) minimum dietary diversity for women (MDD-W), b) mean adequacy ratios (MAR), and c) proportion of women reaching recommended dietary allowances for Indonesians (RDA). The main findings related to these indicators will now be discussed with studies from Indonesia or with the most relevant studies elsewhere. This will discuss the first research question on what predicts a nutritious diet.

One of the most extensive studies, on a national scale, is the Individual Food Consumption Survey. Very recently, Utami & Mubasyiroh (2020) used that data to calculate the dietary diversity of children under 5 years. The study results showed that children's most consumed foods were cereals, roots, and tubers, while the least consumed were fruits and nuts. Although the present study looked at the dietary diversity of women and not children, there are certain similarities such as the expected consumption of staples (100 % of respondents) and low consumption of fruits (40%) and almost no consumption of nuts and seeds (8%). Among pregnant and anaemic women in Javanese Madura island, more than half (58%) reached the MDD-W of 5 food groups or more (Diana et al. 2019). That is slightly higher than in our study area, where the proportion of women reaching the MDD-W was 39% in food recall 1 and 51% in food recall 2. Within food recall 1, only 30% of Minangkabau and 47% of Mandailing women consumed a diverse diet, whereas during food recall 2, 43% of Minangkabau and 59% of Mandailing women reached a diverse diet. The higher dietary diversity captured during the second food recall can be attributed to the fact that food recall 2 was conducted after a market day. Also, the data enumerators might have been more experienced in recalling and probing for foods consumed. The mean dietary diversity score of Mandailing women was 4.6, of Minangkabau women 4.1, and 4.4 in the pooled sample (combining two 24-h food recalls into one usual intake). These findings are very similar to the Sumedang district of West Java, where the mean dietary diversity score of rural lactating women over 3 days was 4.3 food groups (Rahmannia et al. 2019). In West Java, the mean dietary diversity score was higher (5.0 on average) (Mayer and Rohmawati 2019). In the unpublished survey with cocoa farmers in four regions of Indonesia, Pawera et al. (2017) found mean dietary diversity (measured by older IDDS score with 9 groups) to be highest in South Sulawesi (4.7), followed by West Sumatra (4.5), Aceh Barat Daya (4.2) and the lowest in West Sulawesi (4.0). On the country east in a drier and coastal environment of the Komodo island, Gibson et al. (2020) found that maternal dietary diversity was low, with less than one-quarter of mothers reaching MDD-W in either of two food recall periods (21% in wet season and 24% in dry season). The mean dietary diversity score was 3.5 and 3.6 and in the dry season and in the wet season, respectively. This suggests that West Sumatra, and the western part of Indonesia with higher precipitation in general, offer higher availability of food biodiversity than the drier east of the country. Despite the high food biodiversity in the study area, around half of the women did not reach MDD-W. This is unfortunate, and future programs should tap the potential of existing food biodiversity to address this gap.

When looking at the food groups consumed, women in Madura commonly consumed meat, poultry and fish and less eggs or dairy products. Foods from Pulses group such as tempeh and tofu were consumed more than Nuts and seeds. The study found a low consumption of vegetables and fruits, with only half of the women consuming dark green leafy vegetables. Also Other vegetables and fruits, including Vitamin A-rich fruits and vegetables, were consumed by less than 30% (Diana et al. 2019). This pattern is very similar to Minangkabau and Mandailing women in Pasaman Regency, where 85% of women consumed Meat and only 26% consumed Eggs. Both Leafy vegetables and other vegetables were eaten by 62% of women, which is more than in Madura island. In West Java where the diet was more diverse than in our study, more respondents consumed Pulses, Nuts and seeds, Other vegetables and Vitamin A-rich plants (Mayer and Rohmawati 2019). The most commonly consumed food groups in Komodo island were Starchy staples (mainly rice), followed by Meat, Legumes and nuts and a very limited consumption of other groups (Rahmannia et al. 2019).

Considering particular food items, in Madura island, the most consumed green leafy vegetables were moringa leaves, leafy amaranth, water spinach and cassava leaves (Diana et al. 2019). In West Java, bok choy, leafy amaranth and vegetable fern were the most commonly consumed leafy greens (Mayer and Rohmawati 2019). Among more urban women in Bogor, leaves of sweet leaf, leafy amaranth and papaya leaves were the most popular vegetables (Madanijah et al. 2016). The newly proposed indices identified that the most commonly consumed Leafy vegetables in our study were cassava leaves, leafy amaranth, leafy mustard, and vegetable fern. From Other vegetables, Madurese women consumed mainly cucumber, bean sprouts, and cabbage, whereas in our sample, the most popular were eggplant, followed by long bean and french bean. West Javanese preferred to eat tomato, long bean, maize and scallions (Mayer and Rohmawati 2019). In the case of Vitamin A-rich fruits and vegetables, these were limited in Madura and in West Java and the most frequently consumed was carrot in both areas. In the Pasaman Regency, the most consumed species were also carrot and then pumpkin and ripe papaya. Nevertheless, this food group was highly under-consumed as eaten by only 8% of women, though there is a high diversity in this food group in this study compared to other areas (10 species). However, several species in this group have a short seasonality. The ones available more continuously, such as papaya or pumpkin, are not considered as priority foods and are consumed occasionally. Their promotion could have a high impact on diversifying diets.

By reviewing the food composition tables, the present study also identified other locally available nutrient-rich foods. The list could be further used for improving the diets of the communities. However, some of these micronutrient-rich foods are fortified ultra-processed foods rich in sugars and preservatives (e.g., Milo beverage, instant coffee, various biscuits and sweet bread). The foods that should be promoted are vegetables, fruits, pulses, fish and other animal-based local foods.

Looking at the nutrient adequacies and factors that explain them, In Madura island, most of the anaemic women had low adequacy levels of energy and micronutrients with the least adequacy for zinc, calcium, vitamin C and A (iron was mostly adequate due to supplements) (Diana et al. 2019). Family size and gestational age had significant negative associations with better diets. In Sumedang Regency in Java, energy and macronutrient balance were within recommended levels, however, the prevalence of adequacy was less than 50% for niacin, vitamin B6, vitamin C, and less than 60% for calcium, vitamin B12 and vitamin A. In contrast, the prevalence of adequacy for the fortified micronutrients such as iron and zinc was high, reaching 79% and 97%, respectively (Rahmannia et al. 2019). Overall, the mean prevalence of micronutrient adequacy was 57%. Based on over 11 micronutrients, this composite measure was strongly correlated with energy intakes and dietary diversity. The analysis of the national-level data for children´s dietary diversity by Utami and Mubasyiroh (2020) showed that the higher the age, mother's education and economic status, the more diverse the diet. Their results also showed that children´s dietary diversity was higher in urban areas (Utami and Mubasyiroh, 2020). Among rural Minangkabau and Sundanese women in Indonesia, Stefani et al. (2018) found low dietary quality measured by the Healthy Eating Index. The low dietary quality was likely due to the low education and income level, resulting in less diverse and carbohydrate-rich diets. In the Bogor district of Java, Madanijah et al. (2016) identified vitamin C, vitamin A, zinc, calcium and iron as problematic nutrients among lactating and pregnant women. The more wealthy quintiles of women had lower deficiencies, mainly due to increased consumption of leafy vegetables. One particular nutrient-dense local vegetable contributed significantly to the nutrients intake (sweet leaf - *Sauropos androgynus*). In the Komodo island with the lowest dietary diversity from the reviewed studies, the dietary quality was affected by a range of factors. The authors identified variability in incomes, and a food environment in which access to nutrient-dense foods was limited, while nutritionally poor foods were readily available, convenient and highly consumed (Gibson et al. 2020).

An older review of Indonesian women's food intake pointed out the common problematic nutrients like protein, calcium, and iron (Hartriyanti et al. 2012). In our sample from West Sumatra, the most problematic nutrients were folate (RDA reached by 4%), calcium (RDA reached by 9%), vitamin A (RDA reached by 12%) and zinc (RDA reached by 34%). Mandailing women had significantly higher intakes of calcium, iron and protein. This difference is likely caused by the infrastructural factor of being located on the main road with more frequent markets and a cultural factor of different ethnic food habits. Mandailing people traditionally consume leafy vegetables to a more considerable extent than Minangkabau people. However, there was no statistically significant difference in the mean adequacy ratio. The MAR for the pooled sample was 0.64, which means that the diet is adequate by 64% (fully adequate diet would be 100%). The diets were more adequate for macronutrients and less adequate for micronutrients due to the aforementioned problematic nutrients, which lowered the overall MAR. The overall diets appear slightly more adequate than in Sumedang Regency of West Java where the mean probability of adequacy was 57% (Rahmannia et al. 2019).

Our available variables explained dietary adequacy only to a limited extent. The MAR was predicted significantly by food crop species richness and by household non-food expenditures. The other likely positive determinant is education level, which significantly correlates with MAR, yet it turned to be insignificant in the final multiple regression model. Expenditures and education are common factors affecting diets and well-being in Indonesia and globally, but the studies assessing the relationship of diets with agrobiodiversity in Indonesia are limited. There are findings from more intensified and cash crop oriented setting in Jambi in Sumatra, where the low agrobiodiversity and own production had a small association with dietary diversity and the income generated intensive agriculture was found more important for the household diets (Sibhatu & Qaim 2015; Sibhatu & Qaim 2018). A larger and longitudinal study with rural households from across Indonesia found that despite increasing incomes and market access, household dietary diversity has declined with decreased production diversity (Mehraban & Ickowitz 2021). A deeper discussion on this relationship between agrobiodiversity and diets is unfolded in the following chapter.

7.2 Food acquisition pathways: Linkages of agrobiodiversity, markets and diets

The present study contributes to the ongoing critical discussion on the effects of farm production diversity and markets on diets (Sibhatu & Qaim 2018; Jones et al. 2018; Sibhatu & Qaim 2017; Jones 2017; Sibhatu et al. 2015). This second discussion chapter is related to research question 2 on quantifying the food acquisition pathways. It will discuss linkages of crop diversity, markets and diets from nutrition and then from sustainability perspectives.

In our study, food crop species richness predicted, although not strongly, the women's dietary adequacy (MAR). In the regression model, MAR increased by 0.518 by one cultivated food crop species (1 additional crop species would increase MAR by 0.5%). This is an interesting finding showing that higher production diversity increases dietary adequacy. It supports the emerging evidence reviewed by Jones (2017), that there is a small but positive association, and that the magnitude of this relationship varies with the extent of farm diversification. More recently, Jones et al. (2019) further estimated that these magnitudes could be translated that four to ten additional crop species produced would need to be added to increase household diets by one food group. However, this estimation has not been tested. Jones et al. (2019) added that diversification by a few species from the missing food groups accompanied by nutritional knowledge and behaviour change strategies would likely be more effective. In our study, livestock species richness did not correlate and did not predict dietary adequacy. The regression analysis results did not find that purchases on markets (food expenditures) would predict dietary adequacy (MAR). Surprisingly, the non-food expenditures were slightly and significantly predicting the MAR. This might be linked to the household wealth, which the present study did not measure (just indirectly by poverty levels which had no effects on diets). Wealth was, for example, the strongest predictor of household dietary diversity in Malawi (Jones 2017a).

In the longitudinal study of Malawi, besides wealth, crop species richness was also positively associated with household dietary diversity, intake of energy, protein, iron, vitamin A, and zinc (Jones 2017a). Agrobiodiversity was also associated with moderately more diverse and more micronutrient adequate diets among women in Peruvian Andes (Jones et al. 2018). This association was consistent across farms with varying market orientation. Among Mayan Achí people in Guatemala, higher nutritional and dietary diversity scores were positively correlated with higher crop and animal species richness (Luna-González & Sørensen 2018). Market remoteness was negatively correlated with dietary diversity there. In Uganda, Whitney et al. (2018) found many mixed and unexpected relationships and none or only very weak correlations between production diversity and dietary diversity. In Tanzania, Cleghorn (2014) found no significant associations between agrobiodiversity and dietary diversity. Instead, agricultural land cover (croplands) and selling crop production were associated with higher dietary diversity. In Benin, both on-farm diversity and market participation were associated with women's dietary diversity (Bellon et al. 2016). In Kenya, household agrobiodiversity was weakly but positively associated with dietary diversity and micronutrient adequacy (Oduor et al. 2019). In Asia, the studies on these linkages are more limited. In Afghanistan, crop diversity was positively associated with dietary diversity in the regular season, but not in the lean season. In the lean season, livestock diversity and markets become more important (Zanello et al. 2019). In Nepal, production diversity had a mixed relationship with women's dietary diversity (Malapit et al. 2015). Sraboni et al. (2014) found a positive association of food crop diversity with household dietary diversity in Bangladesh (Sraboni et al. 2014). In the Philippines, there was no significant correlation between food group production and individual dietary diversity (Gonder 2011). On the contrary, the study of Bhagowalia et al. (2012) from India found a positive association between crop diversity and household dietary diversity (Bhagowalia et al. 2012).

In Indonesia, there are studies from intense cash crop areas with only remnants of original agrobiodiversity (Sibhatu & Qaim 2015; Sibhatu & Qaim 2016). In this setting, the limited agrobiodiversity and subsistence production often contributed less to dietary diversity than cash income generated through market sales (Sibhatu & Qaim 2015; Sibhatu & Qaim 2018). Nevertheless, a recent study by Mehraban & Ickowitz (2021) with longitudinal data of 2785 rural Indonesian households showed that there had been an overall decline in dietary diversity over time as the production diversity has declined. Specifically, the consumption of nutritious food groups (fruits, legumes, vegetables, and fish) decreased. In our study, it was found that 67% of dietary energy came from the pathway of purchasing food in the local markets. The rest of the energy was obtained by own food production (30% from rice produced in rice fields). Looking further at the pathway of the essential and limiting micronutrient iron, the share of its intake from purchased foods got even more significant (75%), compared to 25% obtained from own sources, namely from rice fields (14%) and cocoa agroforestry (6%). In our study context of rural food systems in West Sumatra, it became clear that consuming purchased foods is currently more important for the communities' diets. In East Java, most of the foods were also purchased from markets or vendors except for vitamin A-rich fruits where 50% were obtained from own gardens (Mayer and Rohmawati 2019). Among smallholders in Ethiopia, own production accounted for 58% of households’ calories, and 42% of the calories consumed are from purchased foods (Sibhatu & Qaim 2017). During all seasons, and especially in the lean season, purchased foods played a much larger role for dietary diversity than subsistence production (Sibhatu & Qaim 2017). In the Usambara Mountains of Tanzania, Powell et al. (2011) showed that 41% of food items, 45% for energy and 33% for protein, were obtained from the farm.

A systematic review by Penafiel et al. (2011) demonstrated that local foods are important sources of energy, micronutrients, and dietary diversification, particularly among rural and indigenous communities in biodiverse ecosystems (Penafiel et al. 2011). In our study, Minangkabau women consumed slightly more foods and nutrients from their own sources compared to Mandailing women, which is likely due to the higher distance of Minangkabau villages from the main road. In West Java, Marten & Abdoellah (1987) quantified that households near to markets had higher annual nutrient consumption not grown by households. But according to these authors, diverse homegardens also plaid an important role as a source of nutrients such as protein, vitamin A, vitamin C and others.

In our study, although a larger share of the consumed foods and nutrients came from the markets, it is important to note that 95% of all foods consumed were traditional and local foods, while only 5% were ultra-processed foods (Pawera et al. 2020). This suggests that local communities continue eating traditional foods, but there is a shift in food acquisition pathways from own production and collection to food procurements in the local markets. In other words of Downs et al. (2020), it is a transition from natural to built food environments.

In this study, no association of MAR with food expenditures suggests that the food from markets might be nutrient-poor in some cases. Further, it appears that despite the own crop production contributes by a lower share to the overall nutrients intake, cultivated food crops are likely nutrient-dense as they predicted dietary adequacy in our study area. A similar observation was made by Powell (2012) where food from farms had higher nutrient density than purchased foods, and they contributed significantly to micronutrient intake. The findings of Reyes-Garcia et al. (2019) with three contemporary hunter-gatherer communities found that the consumption of nutritionally important foods (fruits, vegetables and animal foods) decreased with increasing market integration, while the consumption of foods such as fats and sweets increased. Also Dounias et al. (2007) found that the more remote the Punan hunter-gatherers in Indonesian Borneo, the better their diet, nutritional status and physical fitness. In case of smallholder farmers in Indonesia, Uganda and Kenya, Sibhatu & Qaim (2018) showed that crop species count was positively associated with most dietary indicators. However, when measured by the number of food groups produced, the association turned insignificant in many cases. Further analysis revealed that the generated income was more important for diets (Sibhatu & Qaim 2018). These studies indicate that among remote farming communities and hunter-gatherers, the own food biodiversity is more crucial for diets, contrarily to more commercialized smallholders for which food procurement on markets becomes more important.

Certainly, markets are becoming more critical for diets in the current times, but they may also contribute to the escalation of non-communicable diseases through the consumption of unhealthy and ultra-processed foods (Moubarac et al. 2017; Demmler et al. 2017). Indigenous communities are particularly prone to rapid dietary and lifestyle changes (Kuhnlein 2015). Global trade and markets play a major role in shifting people's habits and indigenous communities tend to increase the consumption of highly processed foods of low nutrient value (Gracy & King 2009; Kuhnlein et al. 2009). Moreover, commercialization and generated income can be spent on nutrient-poor foods or other products and services. This has been demonstrated by some studies where there was a shift from traditional polycultures to cash crop monocultures (e.g., Purwestri et al. 2019). Also, affordability of foods and healthy diets is a significant challenge (Dizon at all. 2019; Jaenicke & Virchow 2013) as especially nutrient-rich and healthy foods such as fruits, vegetables, or eggs are rather expensive. A recent SOFI report (FAO 2020) demonstrated that 50% of the world population cannot afford a healthy diet. In Indonesia, around 38% of households cannot afford it (WFP 2017). In addition, some more rural and remote areas in Indonesia do not have well-developed infrastructure and markets, and the rapid shift from sovereign subsistence to market dependency may not have positive nutritional outcomes but rather contribute to decreased dietary diversity (Mehraban & Ickowitz 2021) and malnutrition (Santika et al. 2019). However, according to Sibhatu & Qaim (2018), there can be an income trade-off. In intensified plantation areas in Indonesia, cultivating too many species was associated with income losses (Sibhatu & Qaim 2018).

Indeed, the relationship between agrobiodiversity and diets is more complex and not linear. There can be numerous confounders and barriers (Timler et al. 2020). Termote et al. (2012) found that a highly biodiverse environment did not translate into a diverse diet in the Democratic Republic of Congo. In Afghanistan, improved crop diversity was positively associated with dietary diversity in the regular season, but not in the lean season. Livestock species diversity and markets became more important in the lean season when the influence of crop diversity was low (Zanello et al. 2019). In fact, seasonality is an important and often limiting factor. In Timor-Leste, seasonality predicted meat intake, which was more likely to be consumed during the dry season. Interestingly, this seasonality was related to the cultural dimension, as the dry season is when more cultural events with meat consumption occur (Bonis-Profumo et al. 2020). Some of our findings also revealed the seasonality limitations. For example, only 40% of women had consumed fruit during the previous day, even though 55 types of fruits were documented in the area. The problem is that most of the fruits are highly seasonal and were not fruiting during the fieldwork. Thus, the fruit intakes were limited and dominated by banana followed by coconut and a few other common and less seasonal species. It is recommended to repeat the dietary assessment in a different period, such as during the fruits season. And to practically overcome seasonality limitations for improving diets, the processing of seasonal food plants should be developed for increasing the availability of nutritious foods throughout the year.

The other factor that adds complexity to the biodiversity-diet linkages is the initial level of agrobiodiversity. Even slight diversification was associated with greater increases in diet diversity among low agrobiodiversity farms than diversification among intermediate or highly diverse farms (Jones et al. 2019). Another issue is the remoteness or stage of market infrastructure. More isolated Minangkabau households with less frequent markets were found to consume slightly more foods and nutrients from own production than Mandailing who are settled around the main road. This observation is similar to the results of Reyes-García et al. (2019) and Powell et al. (2015), showing that natural food environments are more important in more remote communities. As isolated communities become more market integrated, they face changes in their food environments, likely increasing access to processed foods. These food systems changes will make it challenging for communities to continue traditional diets and avoid nutrition transitions that may adversely impact their health and well-being (Reyes-García et al. 2019). To conclude, the relationship between agrobiodiversity and diets is complex, and it may have positive associations in some situations but not in others (Sibhatu & Qaim 2018). In the end, the present study agree with Mehraban & Ickowitz (2021) that it is more critical to achieve healthier diets rather than arguing which pathway is better over the other. Both pathways can be complementary and adjusted to local needs and context.

However, the context is crucial here, and among smallholder farmers, maintaining crop biodiversity may not only provide food and income, but it also serves as a resilience component and buffer to climate change and other biotic and abiotic stresses (Meldrum et al. 2018; Mijatovic et al. 2013). It is also an essential source of different ecosystem services and represents genetic resources and biocultural heritage. Another consideration is sustainability, as intensification and shift to monocrops lead not only to a decreased level of biodiversity but also to higher production risks, chemical input use, and reduced social equity and sustainability as happened in West Java (Abdoellah et al. 2020; Abdoellah et al. 2006). The agriculture and landscape in the study area still remain diverse and relatively sustainable, though the intensification of rice and cash crops is increasing.

Besides biodiversity for nutrition at the species level, more remain to be uncovered at the varieties level and ecosystem/landscape level (Lutaladio et al. 2010; Broegaard et al. 2017).

Changes in agrobiodiversity at the landscape level (for example, aggregation of changes by multiple households or stakeholders in a region) may affect or create new nutrition pathways. For example, diversification at the landscape level may influence the diversity of foods available at local markets, thus increasing the likelihood that income generation can lead to more diverse diets. The ecosystem services provided by enhanced biodiversity at the landscape scale may also initiate positive feedbacks on total farm productivity (Jones et al. 2019). Without a doubt, the landscape heterogeneity should be maintained in the study area for numerous ecosystem services, climate change adaptation and for resilience towards natural disasters such as landslides and floods which are frequent in the region (Rozi 2017). For instance, there were floods in the Mandailing area during the study. It was observed that farmers who only tended rice field were hit hard by losing their rice harvest. On the contrary, livelihood and food security of farmers who had more land-uses such as cocoa agroforestry were less affected.

7.3 Food plant diversity and changes in its use

This chapter elaborates on findings related to research question 3 on what is the richness of food plant diversity and what motivations and barriers affect its persistence and use. Indonesian and especially Javanese homegardens and agroforests have been the subject of many pioneering studies in the past. Generally, these older studies showed that at that time, gardens in Indonesia had an extraordinary diversity of both cultivated and wild plants, many of them useful and edible. Abdoellah & Marten (1986) documented in total of 235 crop species (including medicinal and ornamental plants) cultivated in highly diverse cropping systems in West Java. A follow-up study of these systems from a nutritional perspective found that there was a total of 120 food crops (including spices), and many of the plants being important sources of nutrients (Marten & Abdoellah 1987). Further in Java, Abdoellah et al. (2001) documented 195 plant species in homegardens at a higher altitude, whereas Soemarwoto and Convay (1992) found 272 plant species in lowland homegardens. Hadikusumah (1982) in West Javan village found 112 plant species (of these 45 food plants) in agroforests and 127 species (of these 54 food plants) in homegardens.

In Central Sulawesi, homegardens located at the edge of Lore Lindu National Park contained 149 crop species (Kehlenbeck & Mass 2004). Out of those, 84 were fruits, vegetables and staples (Kehlenbeck 2007). More on the east, in Bali, Sujarwo & Caneva (2015) documented 36 species belonging to 20 families and 29 genera. Out of these, 46% were used as vegetables, 20% as edible fruits, 9% as spices, 2% as edible seeds and the rest as medicine.

In Sumatra, Silalahi & Nisyawati (2018) found 60 food plant species in homegardens of Batak Karo people in North Sumatra. In the southern part of North Sumatra, Nasution et al. (2018) identified 106 species of food plant species (both cultivated and wild) used by the Mandailing people. Michon et al. (1986) characterized the traditional agroforestry systems around Maninjau lake in West Sumatra as diverse forestlike systems integrating native species and commercial crops, mostly coffee, cinnamon or nutmeg. These complex and balanced socio-ecological production systems provided both ecosystem services and livelihood. Besides a few cash crops, there were 28 fruit tree species, around 10 species of vegetables and 20 timber species (Michon et al. 1986).

In the present study, considering all the land-uses, a total of 79 species of food crops which correspond to 98 distinct folk foods were documented. The Minangkabau landscape had a total diversity of 77 food crop species, whereas Mandailing cultivated 64 species in total. In both areas, cocoa agroforests were found as a land-use with the highest total diversity of both cultivated and wild food plants (in total 82 species in Minangkabau and 72 species in Mandailing area), followed by homegardens (51 species in Minangkabau and 45 species in Mandailing area).

Most of the cultivated food crops identified in this study are commonly found across other regions in Indonesia. The food crop species numbers are comparable to the areas in Central Sulawesi (Kehlenbeck 2007) and North Sumatra (Nasution et al. 2018), but higher than in Maninjau area of West Sumatra (Michon et al. 1986), North Sumatra (Silalahi & Nisyawati 2018), and Bali (Sujarwo & Caneva 2015). It appears that the food crop diversity was higher in West Java in the past (Abdoellah et al. 2001; Soemarwoto & Convay 1992; Abdoellah & Marten 1986). However, three decades later, a study revisited the West Javanese homegardes and found massive commercialization and simplification of the gardens to a few species of cash crops (Abdoellah et al. 2020). It is known that increasing population, proximity of markets and the associated commercialisation may lead to a loss of homegarden diversity (Abdoellah et al. 2020; Abdoeallah et al. 2006; Soemarwoto & Conway 1992). Abdoealh et al. (2006) revealed that smallholders who commercialized their homegardens, ate less traditional vegetables and meat with high nutritional value and increased the consumption of instant foods instead. In West Java, profit maximization has become the driver of change. As a result, western vegetables and cash crops such as spring onion, carrots, cabbage, and radish have become dominant in both farmlands and homegardens (Abdoellah et al. 2020). These authors identified a negative impact of homegarden commercialization on food sovereignty and for the food system sustainability.

In this regard, studied West Sumatran homegardens and agroforests remain much more diverse and multifunctional than contemporary Javanese gardens. This can be explained by several factors such as lower intensification pressure, but also the maintenance of customary clan land management (where not individuals but clans are deciding about potential land-use change, and where land is not being sold to outsiders). The role also plays the matriarchal heritage system (where women are more empowered and care for land, family and nutrition). And a last key factor appears to be the ecology of current cash crops in West Sumatra, cocoa and coffee, which are shade tolerant and thus relatively biodiversity-friendly. However, new threats (or opportunities depending on the stakeholder view) are approaching West Sumatra. In the neighbouring West Pasaman Regency which is located in the coastal lowland and where the Minangkabau culture and population is more mixed with migrants, the vast monoculture plantations of oil palm have been rolling out and transforming landscapes and societies (Rusman et al. 2019; Anwar et al. 2019). Here we can see how crucial and fragile the relationship of human culture with land management and biodiversity is.

Besides food crops, the studied locations were found to be still relatively diverse on wild food plants due to the continuity of traditional land-uses and persistence of local culture and knowledge. In total, studied communities in the Pasaman Regency steward traditional knowledge on 85 species of wild food plants (corresponding to 106 plant folk foods). In the Maninjau area, also in West Sumatra, Michon et al. (1986) found around 40 species of wild fruits and vegetables. A study in North Sumatra with Mandailing people in their native territory found 106 food plant species, including wild and cultivated ones (Nasution et al. 2018). Further in North Sumatra, Batak Toba people used 44 wild species for food (Silalahi et al. 2018). Towards the east of the country, Sujarwo et al. (2016) found 86 wild plant species used as food, while in Lombok island, only 22 species were used in the cuisine of Sasak people (Sukenti et al. 2016). Ninety wild edibles, a similar number as in our study, were found in other Asian countries such as in Vietnam by Ogle et al. (2003) and even in the more arid environment of Indian Gujarat by Chauhan et al. (2018). According to Bharucha & Pretty (2010), diversity of 90–100 species of wild foods is an average for Asian and African agricultural and forager communities. However, there are exceptions with much higher diversity of wild food plants such as Meghalaya state of North-East India with 249 species (Sawian et al. 2007), tropical Chinese Han with 185 species (Kang et al. 2012), and Thailand with 87 to 252 species depending on location (Cruz-Garcia & Price 2011).

The overall level of wild food plant diversity in the studied area of West Sumatra appears comparable to other ecologically similar regions, besides subtropical parts of India and tropical

Thailand and China, where local communities tend to use a greater diversity of wild edibles. The present study documented some lesser-known local food plants not commonly used in other regions such as a nut (*Elateriospermum tapos*), leafy vegetables (*Plukenetia corniculata*, *Claoxylon longifolium*), fruits (*Hornstedtia conica*, *Hornstedtia elongata*, *Salacca sumatrana*, *Nephellium mutabile*), and legumes (*Archidendron bubalinum*, and one unidentified legume locally called "kacang tujuh lembar daun" translated as "bean with leaves of seven sheets").

However, despite the richness and positive perceptions of wild food plants among Minangkabau and Mandailing women, their consumption has declined over the last generation, which is a similar trend worldwide. Most of the available studies from various regions have found that socio-cultural factors are the main drivers of the reduced consumption of wild edibles (e.g., Thakur et al. 2017, Serrasolses et al. 2016). The present study found that instead, reduced availability was the most prevalent factor limiting the use and consumption of wild food plants in West Sumatra. This is similar to findings by Chauhan et al. (2018) from India. The reduced availability is driven mainly by agriculture intensification at the farm level, where farmers commonly use chemical inputs.

Minangkabau woman in Simpang village: "In the past, there were more forests, and people were collecting wild fruits and vegetables more. Now people use chemicals in the fields and wild food plants are gone". (adapted from Pawera et al. 2020)

The second most frequently mentioned reasons were related to changes in livelihood and lifestyle. For example, in the past, people were gathering plants more socially and the visits to forests and collection of non-timber forest products were more common. Currently, there is a reduced interest in wild food plants. People mentioned to be busier and that there is less time compared to the past. In addition, taste preferences started to change, especially among the younger generations who interact less with the natural food environment and its foods.

Mandailing woman in Sontang village: "Before people used to eat more wild food plants as there were less cultivated crops. Now more fruits and vegetables are being cultivated, traded and preferred in general." (adapted from Pawera et al. 2020)

The specific barriers to consuming wild food plants were their low availability, time constraints to collect and cook them, their low economic value, and also limited knowledge of their nutrition and health benefits. In contrast, the key motivations for the continued use of wild and local food plants were that they are for free without costs, are natural foods free of chemicals, and that certain species are still abundant.

Minangkabau woman in Simpang village: “Wild edibles are good because they are available and fresh natural food which is for free”. (adapted from Pawera et al. 2020)

The main overall systemic drivers of change appear to be socio-economic factors, agriculture intensification and a changing market and food environment (Pawera et al. 2020). These findings inform us what drivers, barriers and motivations could be addressed to prevent loss of this food biodiversity and leverage its potential for human nutrition and sustainable food systems.

7.4 Socio-economy, diets and food biodiversity in different cultural systems

This chapter reflects research question 4. It will discuss the results in the context of comparing matrilineal Minangkabau and patrilineal Mandailing cultural systems. The socio-economic results showed that the two studied ethnic groups have quite similar living conditions and socio-economic indicators. Although the Mandailing households had a slightly higher likelihood of living in poverty, both groups had a high prevalence of poverty in general. The local government officers mentioned the existence of slightly higher poverty in Mandailing villages. According to them, it is due to more agriculture-based livelihood and that Mandailing have arrived in West Sumatra more recently from the Tapanuli region of North Sumatra. Nevertheless, the household expenditure analysis showed that Mandailing are spending slightly more than Minangkabau (221 USD compared to 211 USD per month). Comparing the ratio of food and non-food expenditures showed that Minangkabau spent 60% of expenditures on food compared to 54% in the case of Mandailing. In general, a higher proportion of the budget spent on food is associated with higher poverty. Wealthier societies spend less than 30% of their income on food, while the average household in the developing countries spends around half of its total budget on food, with these proportions varying from 34 % in Latin America to 61 % in Sub-Saharan Africa (De Hoyos & Lessem 2008). In short, the share of expenditures on food by the studied households is similar to those in Sub-Saharan Africa.

However, this relationship between poverty and food expenditures is not always straightforward. In the farming context, households that produce their own food are actually reducing food expenditures. It was found that both communities are spending very little on fruits and vegetables. This is likely due to their own production and a higher priority of purchasing foods such as fish, chicken, eggs, soy bean foods and other foods that are harder to produce by individual households. Even though Mandailing had slightly higher household expenditures, they were mildly more food insecure than Minangkabau. This is surprising and it may indicate some vulnerability in the Mandailing food system or livelihood strategy. The discussions with farmers revealed a fluctuation in income and purchasing power, following the seasonality of cash crop production, mostly cocoa. Seasonality is known to be a limiting factor for better diets, either through income generation or own production pathways (Ng'endo et al. 2018; Sibhatu & Qaim 2017). According to the observations, Minangkabau community was spending slightly less due to a higher remoteness of their settlements and more self-sufficient fruit and vegetable production. On the contrary, Mandailing tend to spend more as living in a more vibrant and commercial environment along the main road. Here, any possible dietary effect of different cultural kinship and descent was not detected. Rather ethnicity, socio-economic characteristics, and different food environments have shaped the diets and food acquisition pathways.

Comparison of diets showed that Mandailing women had more diverse diets and significantly higher intake of Pulses, Other fruits, Leafy vegetables and Condiments. Minangkabau women had a significantly higher intake of Other vegetables and Sugared (conventional) beverages. Looking at what food groups contribute to dietary energy revealed that Starchy staples, Oils and fats, and Meat groups were the main contributors. The contribution of non-starchy foods to total energy intake was similar for both ethnic groups, 45% in the case of Mandailing and 44% among Minangkabau. This is a bit lower than the global average of 50% but higher than the Indonesian average, which is only 30% (Global Food Security Index 2017). The higher the share of non-starchy staples to dietary energy, the more diverse and less staple-based is the diet, and the higher is the chance of achieving dietary adequacy.

Comparing the nutrient intakes demonstrated differences across several nutrients between the ethnic groups. Mandailing women had significantly higher intakes of calcium, protein, and iron. Despite these differences, the overall MAR was only slightly higher among Mandailing compared to Minangkabau women (0.65 vs 0.63) with no significant difference. Despite only a slight difference in MAR, it should be discussed why Mandailing women had higher dietary diversity and higher intake or nutritious food groups. Based on quantitative data, observations, and FGDs, it appears that it is caused by the two main factors, i.e., infrastructural characteristics of the food environment and by different ethnic food habits.

The first factor is related to the characteristics of the food environment, mainly to markets and also agricultural lands. The studied Mandailing community lived in villages located on the main road, whereas Minangkabau villages were located more inland on the minor road. While both communities indicated a similar distance to the nearest market, it was observed that markets and food stalls were more frequent in Mandailing villages. And the dietary assessment confirmed that Mandailing women obtained more nutrients from foods purchased on markets

(78% and 83% of dietary energy and iron, respectively) compared to Minangkabau (56% and 67% of dietary energy and iron, respectively). In this context, it is surprising that Mandailing households spent less on food expenditures than Minangkabau. Reaching better diets with lower food expenditures indicate either a better purchase of more nutritious food or more efficient uses of own resources. Here the factor of ethnic food habits might be stepping in, ultimately affecting food choice, whether on the market or from own produce (discussed more in the next paragraph). Social and cultural factors, such as ethnicity, are important determinants of food choice (Shepherd 2007). The analysis of expenditures showed that Minangkabau spent more on protein foods but also on less nutritious food snacks, whereas Mandailing spent much more on rice. An earlier study in Indonesia found that households spending a greater share on animal and non-starchy foods had a lower prevalence of child stunting (Sari et al. 2010) and a lower chance of vitamin A deficiency (Campbell et al. 2008). Since the food expenditures did not predict dietary adequacy in our study, it raises the idea that foods from markets are not necessarily nutrient-rich but also nutrient-poor. On the contrary, food crop species richness predicted dietary adequacy, and this suggests that self-produced crops are nutrient-dense. It demonstrates the significance of both natural and built food environments (Downs et al. 2020).

Regarding the second factor of ethnic food habits, it was found that Mandailing tend to eat vegetables (especially leafy vegetables) more often and in higher amounts. This confirms our initial pre-survey observation. On the contrary, Minangkabau diet is known to be more “heavy” with larger amounts of animal foods, coconut milk and thus higher dietary cholesterol (Lipoeto et al. 2004a). Comparing the studied groups, Minangkabau women had a slightly higher fat intake, although not statistically significant. This can be explained by the frequent consumption of coconut milk “santan” among Minangkabau people (though Mandailing are also increasingly consuming it as they are adopting certain Minangkabau food habits into their food culture). Minangkabau diet is well-known for the high use of coconut milk (Hatma 2011), which is used almost daily to make various traditional sauces (gulai). However, the nutritionist and study collaborator, Prof. Lipoeto noted: “Maintenance of santan consumption is crucial for Minangkabau health because those people who stop eating santan foods tend to replace it by high amounts of fried foods rich in processed oils containing unhealthy trans fatty acids. Also, traditional sauces with santan always contain vegetables. Continuing to consume traditional foods with santan and vegetables is one of the best ways to maintain vegetable intake among Minangkabau people”.

The use of coconut milk is thus strongly intertwined with the consumption of vegetables. Moreover, our food intake analysis did not find an extremely high intake of fat, and actually, one-third of the women did not reach RDA of fat (70% of Minangkabau and 66% of Mandailing women reached it). However, the study by Gusnedi et al. (2019) highlighted that Minangkabau people consumed fat (mainly from coconut milk but also from cooking oil) in a higher amount than the national average. Like in our study, they found that the total fat intake remained within the recommended levels, but they uncovered that the intake of saturated fat was high, more than 10% of total energy intake. In this regard, Gusnedi et al. (2019) considered Minangkabau food habits to be related to an unfavourable lipid profile and high prevalence of dyslipidemia, especially among women. Earlier, Djuwita et al. (2003) described a poor dietary fat pattern and a high risk of cardiovascular health disorders. Furthermore, Hatma (2011) found that Minangkabau women had the highest dyslipidemia and the highest plasma total cholesterol from several other ethnic groups. Considering this specific dietary pattern, Gusnedi et al. (2019) developed food-based recommendations specific to Minangkabau people with dyslipidemia. Overall, the specific food habits of the communities seem to be shaped strongly by culture and ethnicity. The present study observed that both matrilineal and patrilineal women play a pivotal role in stewarding traditional food knowledge and practices.

Several studies found that women empowerment is an important determinant of better diets and nutrition (e.g., Sraboni & Quisumbing 2018; Pratley 2016; Malapit et al. 2013). The present study did not quantify the level of women empowerment. However, some of our available variables, such as the level of education, can also be used to indicate women empowerment (e.g., Sinharoy et al. 2007). Though, there was no substantial difference between the ethnic groups and education level reached. Overall, higher education did not associate with better diets, but it did associate with lower food insecurity.

Women from matrilineal culture tend to be more empowered in certain aspects such as property ownership, finance management, and decision making (Keeni et al. 2018; Göttner-Abendroth 2003). However, the extent of this empowerment tends to be reduced by mainstream patrilineal religions and the socio-cultural norm that man is the household head (Keeni et al. 2018). The study of Bhanbhro et al. (2003) pointed out that the Minangkabau people's matrilineal culture promotes the empowerment of women and offers an opportunity for enhancing nutrition and reproductive health (Bhanbhro et al. 2020). Albeit the reasonably equitable social status of Minangkabau women due to the matrilineal culture, the issues such as poverty, limited food access and inadequate nutritional knowledge remain significant challenges

(Bhanbhro et al. 2020). In this context and considering our study findings, the heritage system does not appear to play a significant role in diets and nutritional outcomes. In fact, patrilineal Mandailing women consumed more diverse diets. Therefore, the learning that ethnic food habits and characteristics of the food environment play a more critical role is reinforced here.

A similar finding was reached by comparing gender roles in food provision between matrilineal Khasi and patrilineal Chakhesang tribes in North-East India (Ellena & Nongkynrih 2017). That study demonstrated that both matrilineal and patrilineal women play equally crucial roles in agriculture, agrobiodiversity management and household food provisioning. According to the authors, cultural rules shaped gender relations rather than nutrition and health status. The gender roles were more flexible and egalitarian in the matrilineal society and more hierarchical in the patrilineal society (Ellena & Nongkynrih 2017). Despite more egalitarian principles, similarly as the present study and Bhanhbro et al. (2020) found among Minangakbau, the poor rural context and food insecurity were barriers to better nutrition and health among matrilineal Khasi women in North-East India (Chyne et al. 2017). In that region, women from the neighbouring patrilineal Chakhesang tribe reached better nutritional and health status than women from Khasi tribe and other groups in India (Longvah et al. 2017). According to the authors, the uniquely preserved Chakhesang food system, including 614 plant, animal and insect foods, was a strong reason for better nutritional and health status than among other groups. This discussion further supports the fact that the food environment, dietary habits and socio-economic conditions play a more vital role in nutritional and health status than cultural kinship.

Comparing the food plant diversity between the ethnics showed that Minangkabau maintained a significantly higher number of both wild and cultivated species (in total 121 species compared to 108 species by Mandailing). Although most species overlapped in both communities (77%), the difference was substantial. Minangkabau were found to steward 27 unique species (not occurring in Mandailing area), whilst Mandailing community had only 13 unique species. Minangkabau not only listed more wild food plants but also cultivated a significantly higher number of food crops. This indicates a higher level of traditional plant knowledge among Minangkabau. The richer knowledge and diversity of food plants appears to be intertwined with the stronger relationship of Minangkabau people with their native land that is governed customarily (adat). On the other hand, non-native migrating people are known to maintain lower crop diversity, as Kehlenbeck (2007) demonstrated in Central Sulawesi. An extreme example would be the past governmental transmigration program (moving millions of people from overpopulated islands as Java to outer islands), resulting in high deforestation, land conflicts, and many social costs (Miamoto 2006; Fearnside 1997; Whitten 1987).

Thus, being native to the region undoubtfully affects biodiversity levels. But in the case of unique Minangkabau culture, matrilineal kinship and descent may play a reinforcing role. In Minangkabau society, women inherit the land, and they play an essential role in natural resource management through clan governance. Although the clan meetings and negotiations are led by men (uncles play an essential role in the matrilineal system), the women shape the discussion outcomes by advising men at home ahead of the clan meetings (Ms. Yani Nofri, personal communication, March 2021). From the different land-use types, the most culturally important is irrigated rice field (sawah) which is the inherited property of matrilineage under a lineage head (Benda-Beckmann and Benda-Beckmann 2012). The uncultivated part of the village territory, such as forests, rivers or rangeland is the commons (ulayat) of the village or matriclans, which is governed by the village custom council (Kerapatan Adat Nagari - KAN) (Benda-Beckmann & Benda-Beckmann 2001). Minangkabau people also have a unique traditional village management system known as Nagari, a semi-autonomous regional administrative unit. It can be described as a cluster of a few villages of matriclans. According to Tegnan (2015), Nagari was originally established to settle disputes based on customs and to protect community members' rights, primarily related to the communal land. Although affected, this system survived the Dutch colonial administration and also the Javanese national governmental village (desa) system (Tegnan 2015). The Nagari and customary laws were revived during Indonesia's political decentralisation (Benda-Beckmann & Benda-Beckmann 2001). The present study confirmed the existence of and adherence to the Nagari system in the studied Minangkabau area. Principally, Minangkabau customary land and resource management system has prevented land grabs, large-scale land privatization and any other massive landscape changes. Nonetheless, conflicts with approaching palm oil companies and industrial factories have occurred (Rusman et al. 2019; Tegnan 2015). Nowadays, culture and customary systems are under increasing pressures, and this may result in losses of biological and cultural diversity. Here we infer that women's stronger position in the matrilineal Minangkabau society contributes to more sustainable and equitable stewardship of community lands and natural resources.

Besides different cultural patterns, some other factors may also shape the extent of biodiversity. Our data showed that the food crop species richness was positively correlated with the respondents' age. However, the mean age of Minangkabau women was not higher than that of Mandailing. Consequently, the higher food plant diversity can be attributed to the different culture and relationship of Minangkabau people with their land. Our observation further supports this. Minangkabau households maintained more diverse and complex agroforestry systems, where removal of shade trees has been culturally restricted and allowed only after the clan's agreement (not individuals). The trees in agroforests or community forests are allowed to be cut (i.e., for timber) only in urgent needs or culturally significant occasions such as when a baby girl is born and a new house is being constructed. The high biodiversity of Minangkabau land-uses was also identified by other studies (David et al. 2013; Michon et al. 1986). Mandailing were found to have more individual decision-making, resulting in faster uptake of new practices and intensification of land-uses. Their agroforests, for example, are less diverse with a lower proportion of shade trees but with higher productivity of the cocoa crop. Mandailing are hardworking farmers, spending more time in the field than Minangkabau, and they tend to maximize their efforts and crop yields. Nowadays, removing shade trees in agroforestry is becoming more common in both studied communities, as agriculture intensification (currently mainly maize monocropping) is being encouraged by the government and private sector. It will be up to the communities and strength of their customs, whether the biodiversity across land-uses will remain or not. The matrilineal kinship and inheritance of land may play a role in biodiversity conservation, though the ultimate principle may likely be the overall strength of culture and customary resource management. In this context, the study revealed that Minangkabau customary rules function as a barrier to rapid, inequitable and large-scale extraction of natural resources.

This discussion demonstrated the complexity of relationships between human culture and natural resources. Every socio-ecological system has its strengths, weaknesses, synergies and trade-offs. Our comparison of diets and food biodiversity between different cultural and kinship systems generated two key take away lessons. First, dietary outcomes are determined strongly culturally by ethnic food habits and by food environment rather than by cultural kinship and descent. The second learning, related to food plant diversity, is that the stronger culture and customary resource management results in higher biodiversity. Here, the matrilineal descent seems to play a more critical role by the stronger voice of women, stewarding the cultural values and shaping decisions towards land security and sustainability of resources for future generations. Future research should look more deeply at the gender differences in values and motivations towards land management and natural resource use in matrilineal societies.

8. Conclusions and recommendations

Identifying interventions to improve diet and nutrition in Indonesia is one of the key issues for current research and development in the country. Mainstream approaches, however, have been overlooking the potential of local food biodiversity. Our research found that the studied communities still maintain a high diversity of wild and cultivated food plants due to the persistence of traditional land-use systems and strong local culture. A total of 131 food plant species providing 167 different plant folk foods, were documented. Minangkabau community stewarded a higher diversity of both cultivated and wild food plants than the Mandailing. Both communities perceived local food plants positively, but numerous changes and their drivers have been identified. The main reason for their lower use was decreased availability of local food plants (mainly due to agricultural intensification) and livelihood and lifestyle changes. On the contrary, the key motivations for their continuous use were that they are obtained for free or at a low cost, and that they are perceived as tasty natural and unpolluted foods. The overall drivers of change were mainly socio-economic factors, production intensification and transition of the food environment. The comparison of two different cultural systems showed that customary governance and matrilineal descent appear to contribute to the conservation of biodiversity but not to dietary outcomes, which are more determined by overall ethnic food habits and characteristics of the food environment.

The study found that less than half of women out of 200 studied households reached the minimum dietary diversity and only a minority of women reached recommended dietary allowances (RDA) of the critical micronutrients. The most problematic micronutrients were folate (RDA reached by 4%), calcium (9%), vitamin A (12%), and iron (16%). Overall, the mean adequacy ratio (MAR) aggregated for nine nutrients showed that the diet of the women was adequate by 64%. The comparison revealed that despite having higher agrobiodiversity and higher food insecurity, Mandailing women reached better dietary outcomes (foremost due to higher intake of fruits, pulses and leafy vegetables). Quantifying the food acquisition pathways disclosed that around two-thirds of the consumed nutrients came from markets. This indicates a transition from obtaining food from farms and landscape (natural environments) to local markets (built food environment). Despite that, the vast majority of consumed foods were traditional foods, meaning that people mostly purchase local ingredients. Diversity of cultivated food crops was found important for diet since the regression analysis identified it as the best predictor of dietary adequacy.

The ethnobotanical assessment found that cocoa agroforestry was a land-use with the highest diversity of food plants. At the same time, cocoa farming was the main source of income. The study proposed and tested new quantitative indices for assessing the species contribution, underutilization, and potential for diets. The review of food composition tables demonstrated that the region has numerous micronutrient-rich foods that could contribute to reducing identified micronutrient deficiencies. The findings informed what barriers should be addressed to leverage the potential of biodiversity. The fact that the women perceive local food plants positively provides an opportunity for their potential promotion and mainstreaming into policies and programs in the regions. The communities, government and NGOs should work together to optimize the use of food biodiversity in a participatory and sustainable way. This multi-stakeholder and inclusive approach of food biodiversity conservation could improve human nutrition and health while conserving bio-cultural diversity. The study observed that communities and governments are interested in the potential of local biodiversity and traditional foods. Therefore, despite many drivers of change, the socio-political environment is still enabled for actions leveraging the potential of useful plants and traditional food systems.

The study provides the following recommendations for follow up actions and interventions:

- To raise awareness and understanding of the linkages of biodiversity, nutrition and health. Nutrition knowledge and food biodiversity should be integrated into media and local agriculture, nutrition, health, tourism and education programs in the area.
- The consumption of under-consumed food groups should be improved to diversify the diets. Particularly the intake of fruits, vegetables and pulses should be increased. This could be achieved by promoting local species with higher potential to diversity diets (such as identified multi-food group species). Local markets can also be leveraged for nutrition by improving their infrastructure and promoting more nutritious food choices and purchases.
- Also, the intakes of limiting nutrients (folate, calcium, iron, vitamin A, zinc) should be increased by enhancing the consumption of micronutrient-rich foods or food supplements.
- Developing value chains, small businesses, and processing local plant products could bridge seasonal gaps and lift people out of poverty while conserving biodiversity and landscape.
- To design activities that will support participatory conservation and sustainable use of plants. Besides nutritionally important species, also rare plants should be conserved.
- It is suggested to recognize and maintain cultural values and customary resource management, which appears to affect biodiversity and landscape resilience positively.

And the key recommendations for future research are as follows:

- To explore the linkages of livelihood, food environment and health, particularly in the context of ongoing agricultural intensification with the increased use of agrochemicals.
- To identify and address specific barriers that prevent people from consuming diverse diets. This should follow by designing tailored behaviour change strategies.
- To pilot the development of new nutritious food products and to assess their characteristics, consumer acceptance and impact on consumers´ nutrition and health.
- To conduct a similar study during a different period (e.g., during the fruit season) and apply the newly developed indices for comparing and monitoring food biodiversity consumption.
- To document traditional food recipes and to determine the food composition of neglected and underutilized species and local varieties.
- To assess the feasibility and costs of integrating or developing policies and programs that would upscale the conservation and sustainable use of biodiversity.
- To study the relationship of biodiversity and landscape heterogeneity with climate change resilience and to quantify ecosystem services provided by the landscape.
- To investigate the gender differences in roles, values, and motivations towards sustainable resource management in matrilineal societies more deeply.

The study shared the key findings and suggestions through community awareness materials and multi-stakeholder events in the study area. All over, the study was perceived well by the communities and governments, and it is expected to have a positive impact on nutrition and health, agrobiodiversity stewardship, and food system resilience.

9. References

Abdoellah OS, Schneider M, Nugraha LM, Suparman Y, Voletta CT, Withaningsih S, Pariset, Heptiyanggit A, Hakim L. 2020. Homegarden commercialization: extent, household characteristics, and effect on food security and food sovereignty in Rural Indonesia. Sustainability Science **15**: 797–815.

Abdoellah OS, Hadikusumah HY, Takeuchi K, Okubo S. 2006. Commercialization of homegardens in an Indonesia village: vegetation composition and functional changes. Agroforestry Systems **68**: 1–13.

Abdoellah OS, Takeuchi K, Parikesit G, Gunawan B, Hadikusumah HY. 2001. Pages 167-185 in Proceedings of First Seminar of JSPSDGHE Core University Program in Applied Biosciences ''Toward Harmonisation Between Development and Environmental Conservation in Biological Production''. 21–23 February 2001, The University of Tokyo, Tokyo.

Abdoellah OS, Marten GG. 1986. The Complementary Roles of Homegardens, Upland Fields, and Rice Fields for Meeting Nutritional Needs in West Java. Pages 293-325 in Marten, editor. Traditional Agriculture in Southeast Asia: A Human Ecology Perspective. Westview Press, Colorado.

Ahmed S, Downs SM, Yang C, Chunlin L, Ten Broek N, Ghosh-Jerath S. 2020. Rapid tool based on a food environment typology framework for evaluating effects of the COVID-19 pandemic on food system resilience. Food Security **12** (4): 773-778.

Angkurawaranon C, Jiraporncharoen W, Chenthanakij B, Doyle P, Nitsch D. 2014. Urban environments and obesity in Southeast Asia: a systematic review, meta-analysis and meta-regression. PLoS One **9** (11): e113547.

Anwar K, Ferdinal, Devi R. 2019. Inyiak and Marvin Harris Keepers of Tradition Oral And Ecology: Challenges in the Era of Oil Palm Plantation Expansion in West Sumatra. Pages 147-153 in Proceeding of the 13th International Conference on Malaysia-Indonesia Relations (PAHMI), Sciendo, Padang.

ADB. 2019. Policies to support investment requirements of Indonesia´s food and agriculture development during 2020-2045. Asian Development Bank, IFPRI, BAPPENAS. Asian Development Bank, Manilla.

Arif S, Isdijoso W, Fatah AR, Tamyis AR. 2020. Strategic Review of Food Security and Nutrition in Indonesia 2019–2020 Update. The SMERU Research Institute, Jakarta.

Aryeetey R, Covic N. 2020. A Review of Leadership and Capacity Gaps in Nutrition-Sensitive Agricultural Policies and Strategies for Selected Countries in Sub-Saharan Africa and Asia. Food and Nutrition Bulletin **23**: 0379572120949305.

Beal T, Tumilowicz A, Sutrisna A, Izwardy D, Neufeld L. 2018. A review of child stunting determinants in Indonesia. Maternal and Child Nutrition **14** (4): e12617.

Béné C, Oosterveer P, Lamotte L, Brouwer ID, de Haan S, Prager SD, Talsma EF, Khoury CK. 2019. When food systems meet sustainability—Current narratives and implications for actions. World Development **113**: 116–130.

Benda-Beckmann FV, Benda-Beckmann KV. 2012. Islamic law in a plural context: The struggle over inheritance law in colonial West Sumatra. Journal of the Economic and Social History of the Orient **55**: 771-793.

Benda-Beckmann FV, Benda-Beckmann KV. 2001. Recreating the nagari: decentralisation in West Sumatra. Max Planck Institute for Social Anthropology Working Papers. Working Paper No.31, Max Planck Institute, Halle.

Bellon MR, Ntandou-Bouzitou GD, Caracciolo F. 2016. On-farm diversity and market participation are positively associated with dietary diversity of rural mothers in Southern Benin, West Africa. PloS one **11** (9): e0162535.

Berger J, et al. 2013. The SMILING project: a North-South-South collaborative action to prevent micronutrient deficiencies in women and young children in Southeast Asia. Food and Nutrition Bulletin **34** (2 Suppl): S133–139.

Berti PR, Desrochers RE, Van HP, Ngo TD, Le Thi N, Wangpakapattanawong P. 2016. The process of developing a nutrition-sensitive agriculture intervention: a multi-site experience. Food security **8** (6): 1053-1068.

Bhagowalia P, Headey D, Kadiyala S. 2012. Agriculture, income, and nutrition linkages in India: Insights from a nationally representative survey. Discussion Paper 01195, IFPRI, Washington, DC.

Bhanbhro S, Kamal T, Diyo RW, Lipoeto NI, Soltani H. 2020. Factors affecting maternal nutrition and health: A qualitative study in a matrilineal community in Indonesia. PLoS ONE **15** (6): e0234545.

Bharucha Z, Pretty J. 2010. The roles and values of wild foods in agricultural systems. Philosophical Transactions of the Royal Society B: Biological Sciences **365** (1554): 2913-2926.

Bird FA, Pradhan A, Bhavani RV, Dangour AD. 2019. Interventions in agriculture for nutrition outcomes: a systematic review focused on South Asia. Food Policy **82**: 39-49.

Blackwood E. 2000. Webs of power: Women, kin, and community in a Sumatran village. Rowman & Littlefield Publishers, Boston, Maryland.

Bonis-Profumo G, Stacey N, Brimblecombe J. 2020. Maternal diets matter for children's dietary quality: Seasonal dietary diversity and animal-source foods consumption in rural Timor-Leste. Maternal & Child Nutrition e13071.

Bontoux N. 2009. Landscape Beauty in Minangkabau Homeland: A Study of Agro-Ecotourism Opportunities Around Lake Singkarak. World Agroforestry Center: Bogor.

Borelli T, et al. 2020. Born to eat wild: an integrated conservation approach to secure wild food plants for food security and nutrition. Plants **9** (10): 1299.

Braun V, Clarke V. 2006. Using thematic analysis in psychology. Qualitative Research in Psychology **3**: 77–101.

Broegaard RB, Rasmussen LV, Dawson N, Mertz O, Vongvisouk T, Grogan K. 2017. Wild food collection and nutrition under commercial agriculture expansion in agriculture-forest landscapes. Forest Policy and Economics **94**: 92-101.

Campbell AA, Thorne-Lyman A, Sun K, de Pee S, Kraemer K, Moench-Pfanner R, Sari M, Akhter N, Bloem MW, Semba RD. 2009. Indonesian women of childbearing age are at greater risk of clinical vitamin A deficiency in families that spend more on rice and less on fruits/vegetables and animal-based foods. Nutrition Research **29** (2): 75-81.

Coates J, Swindale A, Bilinsky P. 2007. Household Food Insecurity Access Scale (HFIAS) for measurement of food access: indicator guide (vol. 3). FHI 360/Fanta, Washington.

Colozza D, Avendano M. 2019. Urbanisation, dietary change and traditional food practices in Indonesia: A longitudinal analysis. Social Science & Medicine **233**: 103-112.

Crittenden AN, Schnorr SL. 2017. Current views on hunter-gatherer nutrition and the evolution of the human diet. American Journal of Physiological Anthropology **162**: 84–109.

Cordain L, Eaton SB, Sebastian A, Mann N, Lindeberg S, Watkins BA, O'Keefe JH, Brand-Miller J. 2005. Origins and evolution of the Western diet: Health implications for the 21st century. American Journal of Clinical Nutrition **81**: 341–354.

Cruz-Garcia GS, Price LL. 2011. Ethnobotanical investigation of "wild" food plants used by rice farmers in Kalasin, Northeast Thailand. Journal of Ethnobiology and Ethnomedicine **7**: 33.

Chauhan SH, Yadav S, Takahashi T, Łuczaj Ł, D'Cruz L, Okada K. 2018. Consumption patterns of wild edibles by the Vasavas: a case study from Gujarat, India. Journal of ethnobiology and ethnomedicine **14** (1): 57.

Chyne DAL, Meshram II, Rajendran A, Kodali V, Getti N, Roy P, Kuhnlein HV, Longvah T. 2017. Nutritional status, food insecurity, and biodiversity among the K hasi in Meghalaya, North-East India. Maternal & Child Nutrition **13**: e12557.

Dangour AD, Green R, Häsler B, Rushton J, Shankar B, Waage J. 2012 Linking agriculture and health in low-and middle-income countries: an interdisciplinary research agenda. Proceedings of the Nutrition Society **71** (2): 222-228.

David W, Kasim A, Ploeger A. 2013. Biodiversity and nutrition availability in a matriarchal system in West Sumatra. Pakistan Journal of Nutrition **12** (3): 297-301.

De Hoyos R, Lessem R. 2008. Food Shares in Consumption: New Evidence Using Engel Curves for the Developing World. World Bank, Washington.

Demmler KM, Klasen S, Nzuma JM, Qaim M. 2017. Supermarket purchase contributes to nutrition-related non-communicable diseases in urban Kenya. PloS ONE **12** (9): e0185148.

Development Initiatives. 2020. 2020 Global Nutrition Report: Action on equity to end malnutrition. Development Initiatives, Bristol.

Development Initiatives. 2019. Indonesia nutrition profile. Available from https://globalnutritionreport.org/resources/nutrition-profiles/asia/south-eastern-asia/indonesia/ (accessed October 2020).

Development Initiatives. 2018. 2018 Global Nutrition Report: Shining a light to spur action on nutrition. Development Initiatives, Bristol.

Desmawati, Sulastri D, Lestari Y, Fasrini UU, Afriwardi. 2019. Fat intake is associated with nutritional status in Minangkabau adult women: a crosssectional study. Pakistan Journal of Nutrition **18**: 387-390.

Diana R, Khomsan A, Anwar F, Christianti DF, Kusuma R, Rachmayanti RD. 2019. Dietary Quantity and Diversity among Anemic Pregnant Women in Madura Island, Indonesia. Journal of nutrition and metabolism. Article ID 2647230.

Dizon F, Herforth A, Wang Z. 2019. The cost of a nutritious diet in Afghanistan, Bangladesh, Pakistan, and Sri Lanka. Global Food Security **21**: 38–51.

Djuwita R, Purwantyastuti P, Kamso S. 2003. Nutrients intake pattern of a Minangkabau ethnic group. Makara Journal of Health Research **7** (1): 7-10.

Dounias E, Selzner A, Koizumi M, Levang P. 2007. From sago to rice, from forest to town: The consequences of sedentarization for the nutritional ecology of Punan former hunter-gatherers of Borneo. Food and Nutrition Bulletin **28** (2): (supplement): S294-302.

Downs SM, Ahmed S, Fanzo J, Herforth A. 2020. Food Environment Typology: Advancing an Expanded Definition, Framework, and Methodological Approach for Improved Characterization of Wild, Cultivated, and Built Food Environments toward Sustainable Diets. Foods **9** (532).

Ellena R, Nongkynrih KA. 2017. Changing gender roles and relations in food provisioning among matrilineal Khasi and patrilineal Chakhesang Indigenous rural People of North-East India. Maternal & child nutrition **13** (S3): e12560.

Fanzo J, Holmes M, Junega P, Musinguzi E, Smith IF, Ekesa B, Bergamini N. 2011. Improving nutrition with agricultural biodiversity. A manual on implementing food systems field projects to assess and improve dietary diversity, and nutrition and health outcomes. Bioversity International, Rome.

FAO. 2020. State of Food Security and Nutrition in the World 2020 (SOFI). Food and Agriculture Organization of the United Nations, Rome.

FAO. 2019. The State of the World's Biodiversity for Food and Agriculture 2019. Food and Agriculture Organization of the United Nations, Rome.

FAO. 2018. Sustainable food systems. Concept and framework. A technical brief. Food and Agriculture Organization of the United Nations, Rome. Available from http://www.fao.org/policy-support/tools-and-publications/resources-details/en/c/1160811/ (accessed October 2020).

FAO, FHI360. 2016. Minimum dietary diversity for women Minimum. A guide for measurement. Food and Agriculture Organization of the United Nations, Rome.

FAO. 2016. Compendium of indicators for nutrition-sensitive agriculture. Food and Agriculture Organization of the United Nations (FAO), Rome.

FAO, IFAD, UNICEF, WFP, WHO. 2018. The State of Food Security and Nutrition in the World 2018. Building climate resilience for food security and nutrition. Food and Agriculture Organization of the United Nations, Rome.

Februhartanty J. 2005. Nutrition education: It has never been an easy case for Indonesia. Food and Nutrition Bulletin **26** (2): 265-272.

Fearnside PM. 1997. Transmigration in Indonesia: lessons from its environmental and social impacts. Environmental management **21** (4): 553-570.

Gartaula HN, Niehof A, Quetulio-Navarra M. 2018. Introduction. Pages 15-25 in Niehof A, Gartaula HN, Quetulio-Navarra M, editors. Diversity and change in food wellbeing: cases from Southeast Asia and Nepal. Wageningen Academic Publishers, Wageningen.

Garnett ST, et al. 2018. A spatial overview of the global importance of Indigenous lands for conservation. Nature Sustainability **1** (7): 369.

Gibson E, Stacey N, Sunderland TC, Adhuri DS. 2020. Dietary diversity and fish consumption of mothers and their children in fisher households in Komodo District, eastern Indonesia. PloS one **15** (4): e0230777.

Gibson RS, Ferguson EL. 2008. An interactive 24-hour recall for assessing the adequacy of iron and zinc intakes in developing countries. International Food Policy Research Institute. Washington, D.C. and International Center for Tropical Agriculture (CIAT), Cali, Colombia.

Gibson RS. 2005. Principles of nutritional assessment. Second Edition. Oxford University Press, New York.

Gillespie S, Poole N, van den Bold M, Bhavani RV, Dangour AD, Shetty P. 2019. Leveraging agriculture for nutrition in South Asia: What do we know, and what have we learned? Food Policy **82**: 3-12.

Global Hunger Index. 2020. 2020 Global Hunger Index. Available from https://www.globalhungerindex.org/results.html (accessed October 2020).

Global Food Security Index. 2017. 'Global Food Security Index'. Available from https://cht.hm/2CkqiJS (accessed October 2020).

Gonder CE. 2011. Is Subsistence Enough? Examining the Impact of Household Farm Biodiversity on Dietary Diversity in Bukidnon, Philippines [MSc thesis]. University of Illinois, Urbana-Champaign.

Gounjaria N. 2020. Stunting in Indonesia: Winning the battle but loosing the war? Available from https://www.thejakartapost.com/academia/2020/09/18/stunting-in-indonesia-winning-the-battle-but-losing-the-war.html (accessed October 2020).

Gracey M, King M. 2009. Indigenous health part 1: determinants and disease patterns. The Lancet **374** (9683): 65-75.

Grivetti LE, Ogle BM. 2000. Value of traditional foods in meeting macro- and micronutrient needs: the wild plant connection. Nutrition Research Reviews **13** (1): 31–46.

Göttner-Abendroth H. 2003. “Alam Minangkabau”: The world of the Minangkabau in Indonesia. Pages 163-177 in Göttner-Abendroth H, editor. Matriarchal Societies: Studies on Indigenous Cultures Across the Globe. Peter Lang Publishing: New York.

Gusnedi, Fahmida U, Djuwita R, Witjaksono F, Abdullah M. 2019. Food-based recommendations for Minangkabau women of reproductive age with dyslipidemia. Asia Pacific journal of clinical nutrition **28** (2): 310-320.

Hartriyanti Y, Suyoto PS, Muhammad HF, Palupi IR. 2012. Nutrient intake of pregnant women in Indonesia: a review. Malaysian journal of nutrition **18** (1): 113-124.

Hatma RD. 2011. Lipid profiles among diverse ethnic groups in Indonesia. Acta Medica Indonesiana **43** (1): 4–11.

Hadikusumah H. 1982. The role of homegarden, talun and ricefield in supporting the daily needs of the rural people in Legokkole hamlet, Sadu village, West Java, Indonesia [MSc thesis]. Padjadjaran University, Bandung.

Herforth A, Ahmed S. 2015. The food environment, its effects on dietary consumption, and potential for measurement within agriculture-nutrition interventions. Food Security **7** (3): 505-520.

Herforth A, Harris J. 2014. Understanding and Applying Primary Pathways and Principles. Improving Nutrition through Agriculture. Understanding and Applying Primary Pathways and Principles. Brief #1. Improving Nutrition through Agriculture Technical Brief Series. USAID/Strengthening Partnerships, Results, and Innovations in Nutrition Globally, Arlington.

Heinrich M, Kerrouche S, Bharij KS. 2016. Recent Advances in Research on Wild Food Plants and Their Biological–Pharmacological Activity. Pages 253-269 in De Cortes Sánchez-Mata M, Tardío J, editors. Mediterranean Wild Edible Plants: Ethnobotany and Food Composition Tables. Springer: New York.

Hunter D, Fanzo J. 2013. Introduction: Agricultural biodiversity, diverse diets, and improving nutrition. Pages 1-13 in Hunter D, Borelli T, Mattei F, editors. Diversifying Food and Diets. Routledge, New York.

Hunter D, et al. 2019. The potential of neglected and underutilized species for improving diets and nutrition. Planta **250**: 709–729.

Idler EL, Benyamini Y. 1997. Self-rated health and mortality: a review of twenty-seven community studies. Journal of health and social behavior **1**: 21-37.

Ickowitz A, Rowland D, Powell B, Salim MA, Sunderland TC. 2016. Forests, Trees, and Micronutrient-Rich Food Consumption in Indonesia. PloS ONE **11** (5): e0154139.

INMU. 2014 ASEAN Food Composition Database. Electronic version 1, February 2014. Institute of Nutrition, Mahidol University, Salaya. Available from https://inmu2.mahidol.ac.th/aseanfoods/composition_data.html (accessed September 2020).

Jaenicke H, Virchow D. 2013. Entry points into a nutrition-sensitive agriculture. Food Security **5** (5): 679-692.

Jones AD, Kennedy G, Raneri JE, Borelli T, Hunter D, Creed-Kanashiro HM. 2019. Agricultural Biodiversity and Diets. Evidence, Indicators, and Next Steps. Agrobiodiversity. Pages 213-224 in Zimmerer KA and Haan SD, editors. Agrobiodiversity: Integrating Knowledge for a Sustainable Future. MA: MIT Press, Cambridge.

Jones AD, et al. 2018. Farm-level agricultural biodiversity in the Peruvian Andes is associated withgreater odds of women achieving a minimally diverse and micronutrient adequate diet. Journal of Nutrition **148** (10): 1625–37.

Jones AD. 2017a. On-farm crop species richness is associated with household diet diversity and quality in subsistence-and market-oriented farming households in Malawi. The Journal of nutrition **147** (1): 86-96.

Jones AD. 2017b. Critical review of the emerging research evidence on agricultural biodiversity, diet diversity, and nutritional status in low-and middle-income countries. Nutrition Reviews **75** (10): 769-782.

Kang Y, Luczaj L, Ye S, Zhang S, Kang J. 2012. Wild food plants and wild edible fungi of Heihe valley (Qinling Mountains, Shaanxi, central China): herbophilia and indifference to fruits and mushrooms. Acta Societatis Botanicorum Poloniae **81** (4): 405-413.

Keding GB, Kehlenbeck K, Kennedy G, McMullin S. 2017. Fruit production and consumption: practices, preferences and attitudes of women in rural western Kenya. Food Security **9** (3): 453-69.

Keeni M. Takashino N, Nongkynrih AK, Fuyuki K. 2018. Women Empowerment in a Rural Matrilineal Society of Meghalaya, India. Journal of Asian Rural Studies **2** (2): 144-152.

Kennedy G, Stoian D, Hunter D, Kikulwe E, Termote C. 2017. Food biodiversity for a healthy, diverse diets. Pages 23-52 in Bioversity International, editor. Mainstreaming Agrobiodiversity in Sustainable Food Systems: Scientific Foundations for an Agrobiodiversity Index. Bioversity International, Rome.

Kennedy GL, Pedro MR, Seghieri C, Nantel G, Brouwer, I. 2007. Dietary diversity score is a useful indicator of micronutrient intake in non-breast-feeding Filipino children. The Journal of nutrition **137** (2): 472-477.

Kehlenbeck K, Maass BL. 2004. Crop diversity and classification of homegardens in Central Sulawesi, Indonesia. Agroforestry systems **63** (1): 53-62.

Kehlenbeck K. 2007. Rural Homegardens in Central Sulawesi, Indonesia: An Example for a Sustainable Agro-Ecosystem? [PhD thesis]. University of Göttingen, Göttingen.

Khomsan A, Anwar F, Sukandar D, Riyadi H, Mudjanto ES, Wigna W. 2012. Suku Baduy. Aspek Sosio-Budaya Gizi Dan Sistem Pangan. IPB Press, Bogor.

Khoury CK, Bjorkman AD, Dempelwolf H, Ramirez-Villegas J, Guarino L, Jarvis A, Rieseberg LH, Struik PC. 2014. Increasing homogeneity in global food supplies and the implications for food security. Proceedings of the National Academy of Sciences of the USA **111** (11): 4001–4006.

Kosmaryandi N. 2005. Landscape planning and management of Minangkabau land. Media Konservasi **9** (1): 33-37.

Kuhnlein HV. 2015. Food system sustainability for health and well-being of Indigenous Peoples. Public health nutrition **18** (13): 2415-2424.

Kuhnlein HV. 2013. Indigenous peoples' food systems & well-being: interventions & policies for healthy communities. Centre for Indigenous Peoples' Nutrition and Environment, Food and Agriculture Organization of the United Nations, Rome.

Kuhnlein HV, Erasmus B, Spigelski D. 2009. Indigenous peoples' food systems: the many dimensions of culture, diversity and environment for nutrition and health. Centre for Indigenous Peoples' Nutrition and Environment, Food and Agriculture Organization of the United Nations, Rome.

Kuhnlein HV, Receveur O. 1996. Dietary change and traditional food systems of indigenous peoples. Annual review of nutrition **16** (1):417-42.

Lachat C, et al. 2018. Dietary species richness as a measure of food biodiversity and nutritional quality of diets. Proceedings of the National Academy of Sciences **115** (1): 127-132.

Lipoeto NI, Lin GK, Angeles-Agdeppa I. 2012. Food consumption patterns and nutrition transition in South-East Asia. Public Health and Nutrition **16** (9): 1673-1643.

Lipoeto NI, Agus Z, Oenzil F, Wahlqvist M, Wattanapenpaiboon N. 2004a. Dietary intake and the risk of coronary heart disease among the coconut-consuming Minangkabau in West Sumatra, Indonesia. Asia Pacific Journal of Clinical Nutrition **13**: 377–384.

Lipoeto NI, Wattanapenpaiboon N, Malik A, Wahlqvist ML. 2004b. Nutrition transition in west Sumatra, Indonesia. Asia Pacific journal of clinical nutrition **13** (3): 312-316.

Lipoeto NI, Agus Z, Oenzil F, Masrul M, Wattanapenpaiboon N, Wahlqvist ML. 2001. Contemporary minangkabau food culture in West Sumatra, Indonesia. Asia Pacific journal of clinical nutrition **10** (1): 10-16.

Longvah T, Khutsoh B, Meshram II, Krishna S, Kodali V, Roy P, Kuhnlein HV. 2017. Mother and child nutrition among the Chakhesang tribe in the state of Nagaland, North-East India. Maternal and Child Nutrition **13**: e12558

Lubis A-R. 2005. Mandailing islam across borders. Taiwan Journal of Southeast Asian Studies **2** (2): 55-98.

Luna-González DV, Sørensen M. 2018. Higher agrobiodiversity is associated with improved dietary diversity, but not child anthropometric status, of Mayan Achí people of Guatemala. Public health nutrition **21** (11): 2128-2141.

Lutaladio N, Burlingame B, Crews J. 2010. Horticulture, biodiversity and nutrition. Journal of Food Composition and Analysis **23** (6): 481-485.

Macbeth HM, MacClancy J. 2004. Researching food habits: methods and problems (Vol. 5). Berghahn Books, USA.

Madanijah S, Rimbawan R, Briawan D, Zulaikhah Z, Andarwulan N, Nuraida L, Sundjaya T, Murti L, Bindels J. 2016. Nutritional status of lactating women in Bogor district, Indonesia: cross-sectional dietary intake in three economic quintiles and comparison with pre-pregnant women. British Journal of Nutrition **116**: S67–74.

Malapit HJ, Kadiyala S, Quisumbing AR, Cunningham K, Tyagi P. 2015. Women's empowerment mitigates the negative effects of low production diversity on maternal and child nutrition in Nepal. The journal of development studies **51** (8): 1097-1123.

Malapit HJ, Kadiyala S, Quisumbing AR, Cunningham K, Tyagi P. 2013. Women's empowerment in agriculture, production diversity, and nutrition: Evidence from Nepal. International Food Policy Research Institute (IFPRI). Discussion Paper 01313.

Martin GJ. 2004. Ethnobotany: A methods manual. Plants and People International Conservation. Chapman and Hall, London.

Marten G, Abdoellah OS. 1987. Crop diversity and nutrition in West Java. Ecology of Food and Nutrition **21**: 17-43.

Mauri M, Elli T, Caviglia G, Uboldi G, Azzi MA. 2017. Visualisation Platform to Create Open Outputs. Proceedings of the 12th Biannual Conference on Italian SIGCHI Chapter, Cagliari, Italy, 18–20 September 2017. Available from https://rawgraphs.io/about/ (accessed October 2020).

Mayer A-E, Rohmawati N. 2019. Indonesia's triple burden of malnutrition. A call for urgent policy change. Jember University and IIED, Jakarta.

McCune LM, Kuhnlein HV. 2011. Assessments of indigenous peoples' traditional food and nutrition systems. Pages 249-266 in Anderson EN, Pearsall D, Hunn E, Turner N, editors. Ethnobiology. John Wiley & Sons, New Jersey.

McDade TW, Reyes-García V, Blackinton P, Tanner S, Huanca T, Leonard WR. 2007. Ethnobotanical knowledge is associated with indices of child health in the Bolivian Amazon. Proceedings of the National Academy of Sciences of the USA **104** (15): 6134-6139.

Mehraban N, Ickowitz A. 2021. Dietary diversity of rural Indonesian households declines over time with agricultural production diversity even as incomes rise. Global Food Security **28**: 100502.

Meldrum G, Mijatović D, Rojas W, Flores J, Pinto M, Mamani G, Condori E, Hilaquita D, Gruberg H, Padulosi S. 2018. Climate change and crop diversity: farmers' perceptions and adaptation on the Bolivian Altiplano. Environment, Development and Sustainability **20** (2): 703-730.

Miyamoto M. 2006. Forest conversion to rubber around Sumatran villages in Indonesia: Comparing the impacts of road construction, transmigration projects and population. Forest Policy and Economics **9** (1): 1-12.

Michon G, Mary F, Bompard J. 1986. Multistoried agroforestry garden system in West Sumatra, Indonesia. Agroforestry Systems **4** (4): 315-338.

Mijatović D, Van Oudenhoven F, Eyzaguirre P, Hodgkin T. 2013. The role of agricultural biodiversity in strengthening resilience to climate change: towards an analytical framework. International journal of agricultural sustainability **11** (2): 95-107.

MOEF. 2014. The Fifth National Report of Indonesia to the Convention on Biological Diversity. Ministry of Environment and Forestry of Indonesia. Ministry of Environment and Forestry, Jakarta.

MOH. 2019. Basic Health Research in 2018. Ministry of Health of Republic Indonesia, Jakarta.

MOH. 2018a. Health profile of West Sumatra province in 2016. Ministry of Health of West Sumatra, Padang.

MOH. 2018b. Composition Table of Indonesian Food. Ministry of Health Republic of Indonesia, Jakarta. Available from http://www.panganku.org/id-ID/beranda (accessed October 2020).

MOH. 2014a. Dietary Guideline for Indonesians. Ministry of Health Indonesia, Jakarta.

MOH. 2014b. Food Photo Book. For the Individual Consumption Survey. Ministry of Health Indonesia, Jakarta.

MOH. 2013. Recommended Dietary Allowances for Indonesian People. Ministry of Health Indonesia, Jakarta.

MOH. 1996. 13 Messages on Balanced Diets. Ministry of Health Republic of Indonesia, Jakarta.

Moubarac JC, Batal M, Louzada ML, Steele EM, Monteiro CA. 2017. Consumption of ultra-processed foods predicts diet quality in Canada. Appetite **108**: 512-520.

Nasution A, Chikmawati T, Walujo EB, Zuhud EA. 2018. Ethnobotany of Mandailing Tribe in Batang Gadis National Park. Journal of Tropical Life Science **8** (1): 228159.

Niehof A. 2010. Food, diversity, vulnerability and social change. Research findings from insular Southeast Asia. Mansholt publication series (Vol. 9). Wageningen Academic Publishers, Wageningen.

Ng'endo M, Bhagwat S, Keding GB. 2018. Contribution of Nutrient Diversity and Food Perceptions to Food and Nutrition Security Among Smallholder Farming Households in Western Kenya: A Case Study. Food and nutrition bulletin **39** (1): 86-106.

Oduor FO, Boedecker J, Kennedy G, Termote C. 2019. Exploring agrobiodiversity for nutrition: Household on-farm agrobiodiversity is associated with improved quality of diet of young children in Vihiga, Kenya. Plos one **14** (8): e0219680.

Ogle BM, Tuyet HT, Duyet HN, Dung NN. 2003. Food, feed or medicine: the multiple functions of edible wild plants in Vietnam. Economic Botany **57** (1): 103-117.

Pandey VL, Dev SM, Jayachandran U. 2016. Impact of agricultural interventions on the nutritional status in South Asia: A review. Food policy **62**: 28-40.

Pawera L, Khomsan A, Zuhud EA, Hunter D, Ickowitz A, Polesny Z. 2020. Wild food plants and trends in their use: From knowledge and perceptions to drivers of change in West Sumatra, Indonesia. Foods **9** (9): 1240.

Pawera L, Khomsan A, Zuhud EAM, Lipoeto N, Polesny Z, Hunter D. 2019. Developing new quantitative indices for assessing the potential of edible species for dietary diversity. Agriculture, Nutrition and Health Academy Week, 24-28. 6. 2019, Hyderabad, India (oral presentation).

Pawera L, Lipoeto NI, Khomsan A, Zuhud EAM. 2018. Food plants of Minang and Mandailing cocoa farmers in Pasaman district, West Sumatra, Indonesia. A Community Guidebook for Biodiversity for nutrition and health. Swisscontact, Jakarta.

Pawera L, Tumova B, Hunter D. 2017. Survey of local food plants and dietary diversity of small-scale cocoa farmers in Sulawesi and Sumatra and its implications for a large-scale nutrition project. Symposium of Biodiversity and Wild Edible Species, 3-5. 4. 2017, Antalya, Turkey (oral presentation).

Pelto GH, Goodman AH, Dufour DL. 2013. The biocultural perspective in nutritional anthropology. Pages 1-9 in Goodman AH, Dufour DL, Pelto GH, editors. Nutritional anthropology. Mayfield Publishing Company, Mountain View, CA.

Pelto GH, Pelto GH, Messer E. 1989. Research methods in nutritional anthropology. United Nations University Press, Hong Kong.

Penafiel D, Lachat C, Espinel R, Van Damme P, Kolsteren P. 2011. A systematic review on the contributions of edible plant and animal biodiversity to human diets. EcoHealth **8** (3): 381-99.

Pieroni A, Pawera L, Shah GM. 2016. Gastronomic Ethnobiology. Pages 53-62 in Albuquerque UP, Nóbrega A, Romulo R, editors. Introduction to Ethnobiology. Springer, New York.

Pieroni A, Price LL. 2006. Eating and Healing. Traditional Food as Medicine. Haworth Press: London and New York.

PAR. 2018. Assessing Agrobiodiversity: A Compendium of Methods; Platform for Agrobiodiversity Research: Rome.

Powell B, Thilsted SH, Ickowitz A, Termote C, Sunderland T, Herforth A. 2015. Improving diets with wild and cultivated biodiversity from across the landscape. Food Security **7** (3): 535-554.

Powell B. 2012. Biodiversity and human nutrition in a landscape mosaic of farms and forests in the East Usambara Mountains, Tanzania [PhD thesis]. McGill University, Montreal.

Powell B, Hall J, Johns T. 2011. Forest cover, use and dietary intake in the East Usambara Mountains, Tanzania. International Forestry Review **13** (3): 305-317.

Pratley P. 2016. Associations between quantitative measures of women's empowerment and access to care and health status for mothers and their children: a systematic review of evidence from the developing world. Social Science Medicine **169**: 119–131.

Purwestri RC, Powell B, Rowland D, Wirawan NN, Waliyo E, Lamanepa M, Habibie Y, Ickowitz A. 2019. From growing food to growing cash: understanding the drivers of food choice in the context of rapid agrarian change in Indonesia. Info Brief. CIFOR, Bogor.

Rahmannia S, Diana A, Luftimas DE, Gurnida DA, Herawati DM, Houghton LA, Gibson RS. 2019. Poor dietary diversity and low adequacy of micronutrient intakes among rural Indonesian lactating women from Sumedang district, West Java. PloS one **14** (7): e0219675.

Reyes-García V, Powell B, Díaz-Reviriego I, Fernández-Llamazares Á, Gallois S, Gueze M. 2019. Dietary transitions among three contemporary hunter-gatherers across the tropics. Food Security **11** (1): 109-122.

Ruel MT, Quisumbing AR, Balagamwala M. 2018. Nutrition-sensitive agriculture: What have we learned so far? Global Food Security **17**: 128-153.

Rusman B, Agustian, Aprisal. 2019. Changes in Soil Chemical and Physical Properties of Andisols under Oil Palm Small holder in the West Pasaman District of West Sumatra. Pages 1-12. in IOP Conference Series: Earth and Environmental Science (Vol. 347, No. 1, p. 012040), IOP Publishing.

Ryan GW, Bernard HR. 2003. Techniques to Identify Themes. Field Methods **15**: 85–109.

Santika T, Wilson KA, Meijaard E, Budiharta S, Law EE, Sabri M, Struebig M, Ancrenaz M, Poh TM. 2019. Changing landscapes, livelihoods and village welfare in the context of oil palm development. Land Use Policy **87:** 104073.

Sari M, De Pee S, Bloem MW, Sun K, Thorne-Lyman AL, Moench-Pfanner R, Akhter N, Kraemer K, Semba RD. 2010. Higher household expenditure on animal-source and nongrain foods lowers the risk of stunting among children 0–59 months old in Indonesia: implications of rising food prices. The Journal of nutrition **140** (1): 195S-200S.

Sawian JT, Jeeva S, Lyndem FG, Mishra BP, Laloo RC. 2007. Wild edible plants of Meghalaya, North-east India. Natural Product Radiance **6** (5): 410-426.

Schreiner M. 2012. A simple poverty scorecard for Indonesia. Progress out of Poverty Index. Microfinance Risk Managment, L.L.C, Washington.

Sekiyama M, Roosita K, Ohtsuka R. 2017. Locally Sustainable School Lunch Intervention Improves Hemoglobin and Hematocrit Levels and Body Mass Index among Elementary Schoolchildren in Rural West Java, Indonesia. Nutrients **9** (8): E868.

Serrasolses G, Calvet-Mir L, Carrió E, D'Ambrosio U, Garnatje T, Parada M, Vallès J, Reyes-García V. 2016. A matter of taste: Local explanations for the consumption of wild food plants in the Catalan Pyrenees and the Balearic Islands. Economic Botany **70** (2): 176-189.

Setyowati D, Andarwulan N, Giriwono PE. 2018. Processed and ultraprocessed food consumption pattern in the Jakarta Individual Food Consumption Survey 2014. Asia Pacific journal of clinical nutrition **27** (4): 840.

Shepherd R. 1999. Social determinants of food choice. Proceedings of the Nutrition Society **58** (4): 807-812.

Sibhatu KT, Qaim M. 2018. Farm production diversity and dietary quality: linkages and measurement issues. Food Security **10**: 47–59.

Sibhatu KT, Qaim M. 2017. Rural food security, subsistence agriculture, and seasonality. PloS one **12** (10): e0186406.

Sibhatu KT, Krishna VV, Qaim M. 2015. Production diversity and dietary diversity in smallholder farm households. Proceedings of the National Academy of Sciences **112** (34): 10657-10662.

Silalahi M, Nisyawati N. 2018. The ethnobotanical study of edible and medicinal plants in the homegarden of Batak Karo sub-ethnic in North Sumatra, Indonesia. Biodiversitas Journal of Biological Diversity **19** (1): 229-238.

Silalahi M, Pikoli MR, Sugoro I. 2018. Ethnobotanical study of non-cultivated food plants used by the local Batak Toba sub-ethnic community, in Peandungdung Utara village, Indonesia. Jurnal Pengelolaan Sumberdaya Alam dan Lingkungan Hidup **8**: 264–270.

Sinharoy SS. Waid JL. Haardörfer R, Wendt A, Gabrysch S. Yount KM. 2018. Women's dietary diversity in rural Bangladesh: Pathways through women's empowerment. Maternal & child nutrition 14 (1): e12489.

SMERU. 2015. Food and Nutrition Security in Indonesia: A Strategic Review. Improving food and nutrition security to reduce stunting. The SMERU Research Institute, Jakarta.

Soemarwoto O, Conway GR. 1992. The javanese homegarden. Journal for Farming Systems Research-Extension **2** (3): 95-118.

Sraboni E, Quisumbing A. 2018. Women's empowerment in agriculture and dietary quality across the life course: evidence from Bangladesh. Food policy **81**: 21-36.

Sraboni E, Malapit HJ, Quisumbing AR, Ahmed AU. 2014. Women's empowerment in agriculture: What role for food security in Bangladesh? World Development **61**: 11-52.

Stefani S, et al. 2018. Dietary quality of predominantly traditional diets is associated with blood glucose profiles, but not with total fecal Bifidobacterium in Indonesian women. PLoS ONE **13** (12): e0208815.

Sthapit B, Rana R, Subedi A, Gyawali S, Bajracharya J, Chaudhary P, Joshi BK, Sthapit S, Joshi KD, Upadhaya MP. 2012. Participatory Four-cell Analysis (FCA) for Understanding Local Crop Diversity. Pages 13-16 in Sthapit BR, Shrestha P, Upadhyay MP, editors. On-farm Management of Agricultural Biodiversity in Nepal: Good Practices. NARC/LI-BIRD, Bioversity International, Nepal.

Stockholm Resilience Centre. 2020. The planetary health diet. New Lancet report demonstrates why diet and food production must radically change to improve health and avoid potentially catastrophic damage to the planet. Available from https://www.stockholmresilience.org/research/research-news/2019-01-17-the-planetary-health-diet.html (accessed October 2020).

Sujarwo W, Arinasa IB, Caneva G, Guarrera PM. 2016. Traditional knowledge of wild and semi-wild edible plants used in Bali (Indonesia) to maintain biological and cultural diversity. Plant Biosystems-An International Journal Dealing with all Aspects of Plant Biology **150** (5): 971-976.

Sujarwo W, Caneva G. 2015. Ethnobotanical study of cultivated plants in homegardens of traditional villages in Bali (Indonesia). Human Ecology **43** (5): 769-78.

Sukenti K, Hakim L, Indriyani S, Purwanto Y, Matthews PJ. 2016. Ethnobotanical study on local cuisine of the Sasak tribe in Lombok Island, Indonesia. Journal of Ethnic Foods **3** (3): 189-200.

Surono IS. 2015. Traditional Indonesian dairy foods. Asia Pacific Journal of Clinical Nutrition **24**: S26–S30.

Swisscontact. 2016. Impact study: Good Nutritional Practices Project. A component of the Sustainable Cocoa Production Program in Indonesia. Swisscontact, Jakarta.

Tardío J, Pardo-de-Santayana M. 2008. Cultural importance indices: a comparative analysis based on the useful wild plants of Southern Cantabria (Northern Spain). Economic Botany **62** (1): 24-39.

Tegnan H. 2015. Legal pluralism and land administration in West Sumatra: The implementation of local and nagari governments' regulations on communal land tenure. The Journal of Legal Pluralism and Unofficial Law **47** (2): 312-323.

Termote C, Meyi MB, Djailo BD, Huybregts L, Lachat C, Kolsteren P, Van Damme P. 2012. A biodiverse rich environment does not contribute to a better diet: a case study from DR Congo. PloS one **7** (1): e30533.

Thakur D, Sharma A, Uniyal SK. 2017. Why they eat, what they eat: patterns of wild edible plants consumption in a tribal area of Western Himalaya. Journal of Ethnobiology and Ethnomedicine **13** (1): 70.

Timler C, Alvarez S, DeClerck F, Remans R, Raneri J, Carmona NE, Mashingaidze N, Chatterjee SA, Chiang TW, Termote C, Yang RY. 2020. Exploring solution spaces for nutrition-sensitive agriculture in Kenya and Vietnam. Agricultural Systems **180**: 102774.

Toledo A, Burlingame B. 2006. Biodiversity and nutrition: a common path toward global food security and sustainable development. Journal of Food Composition and Analysis **19**: 477-483.

Torheim LE, Barikmo I, Parr CL, Hatløy A, Ouattara F, Oshaug A. 2003. Validation of food variety as an indicator of diet quality assessed with a food frequency questionnaire for Western Mali. European Journal of Clinical Nutrition **57** (10): 1283-1291.

Tugby E. 1963. Land utilization and settlement patterns in upper Mandailing, Sumatra. [PhD thesis]. the Australian National University, Sydney.

UNICEF. 2018. Nutrition Capacity Assessment in Indonesia. United Nations Children's Fund, Jakarta.

UNICEF. 2016. Children in South East Asia face a 'double burden' of obesity and undernutrition, new report finds. United Nations Children's Fund. Available from https://www.unicef.org/png/press-releases/children-south-east-asia-face-double-burden-obesity-and-undernutrition-new-report (accessed October 2020).

USDA. 2019. Department of Agriculture, Agricultural Research Service. FoodData Central (2019) Available from https://fdc.nal.usda.gov/index.html (accessed March 2020).

Utami NH, Mubasyiroh R. 2020. Food diversity and its relationship with the nutrition status of children: Analysis of Individual Food Consumption Survey. GIZI INDONESIA **43** (1): 37-48.

Vermeulen SJ, Wellesley L, Airey S, Singh S, Agustina R, Izwardy D, Saminarsih D. 2019. Healthy diets from sustainable production: Indonesia. Chatham House, the Hoffmann Centre for Sustainable Resource Economy, EAT, the Human Nutrition Research Center at the University of Indonesia, Jakarta.

Vogl CR, Vogl-Lukasser B, Puri RK. 2004. Tools and methods for data collection in ethnobotanical studies of homegardens. Field methods **16** (3): 285-306.

Weinberger K. 2013. Home and community gardens in Southeast Asia: potential and opportunities for contributing to nutrition-sensitive food systems. Food security **5**: 847-856.

Westphal E, Jansen PCM. 1986. Plant Resources of South-East Asia. Proposal for a handbook. Centre for Agricultural Publishing and Documentation (Pudoc), Wageningen.

Whitney C. 2020. Ethnobotany, R. Quantitative ethnobotany analysis with ethnobotanyR. Available from https://cran.r-project.org/web/packages/ethnobotanyR/vignettes/ethnobotanyr_vignette.html (accessed August 2020).

Whitney CW, Luedeling E, Hensel O, Tabuti JR, Krawinkel M, Gebauer J, Kehlenbeck K. 2018. The role of homegardens for food and nutrition security in Uganda. Human Ecology **46** (4): 497-514.

Whitten T, Damanik SJ, Anwar J, Hisyam N. 2000. The Ecology of Sumatra. Periplus Editions: Hong Kong.

Whitten AJ. 1987. Indonesia's transmigration program and its role in the loss of tropical rain forests. Conservation Biology **1** (3): 239-246.

Widyatmoko D. 2019. Strategy and innovation in conservation of Indonesian plants for sustainable use. Pages 1-22 in Asngad A, et al. editors. SNPBS Proceedings from the National Seminar on Biology and Science Education. Universitas Muhammadiyah, Surakarta.

Willett W, et al. 2019. Food in the Anthropocene: the EAT–Lancet Commission on healthy diets from sustainable food systems. The Lancet **393** (10170): 447-492.

WFP. 2017. Cost of the Diet Study Results. World Food Programme and Kementarian PPN/Bappenas, Jakarta.

WHO. 2003. Promoting fruit and vegetable consumption around the world. Global Strategy on Diet, Physical Activity and Health. World Health Organization: Geneva. Available from https://www.who.int/dietphysicalactivity/fruit/en/#:~:text=A%20recently%20published%20WHO%2FFAO,alleviation%20of%20several%20micronutrient%20deficiencies%2C (accessed October 2020).

Zanello G, Shankar B, Poole N. 2019. Buy or make? Agricultural production diversity, markets and dietary diversity in Afghanistan. Food Policy **87**: 101731.

Zinöcker M, Lindseth I. 2018. The Western Diet–Microbiome-Host Interaction and Its Role in Metabolic Disease. Nutrients **10** (3): 365.

10. Appendices

List of appendices

Appendix 1: The list of documented food plants and associated plant folk foods

Table A1 Diversity of food plants and associated folk foods used by Minangkabau and Mandailing communities in the Pasaman Regency, West Sumatra

Local name[1]	English name	Latin name (and voucher number)	Local food category	Plant part used	Plant status	Habitat[2]	Citations (C) and Occurence (O)[3]
A) Food group – STARCHY STAPLES:							
Jagung (Mi, Ma)	Maize	*Zea mays* L.	Vegetable	Seed	Cultivated	Fi, Hg, Af	O: 4% Ma, 12% Mi
Kentang (Mi, Ma)	Potato	*Solanum tuberosum* L.	Staple crop	Tuber	Cultivated	Market	Market only
Padi (Mi, Ma)	Rice	*Oryza sativa* L.	Staple crop	Seed	Cultivated	Rf	O: 66% Ma, 76% Mi
Sukun (Mi, Ma)	Breadfruit	*Artocarpus altilis* (Parkinson ex F.A.Zorn) Fosberg	Fruit	Fruit	Cultivated	Af	O: 0% Ma, 1% Mi
Talas hitam (Mi)	Tania	*Xanthosoma sagittifolium* (L.) Schott (LP56)	Staple crop	Tuber	Cultivated, wild	Af	C: 0 Ma, 1 Mi
Talas (Mi); Suhat (Ma)	Taro	*Colocasia esculenta* (L.) Schott (LP16)	Staple crop	Tuber	Cultivated, wild	Ae, Af, Fi	C: 16 Ma, 37 Mi; O: 1 Ma, 10 Mi
Ubi singkong, Ubi kayu (Mi, Ma)	Cassava	*Manihot esculenta* Crantz	Staple crop	Tuber	Cultivated, wild	Ag, Ho, Fi	C: 30 Ma; 44 Mi; O: 80% Ma, 78% Mi
Ubi jalar (Mi, Ma)	Sweet potato	*Ipomoea batatas* (L.) Lam.	Staple crop	Tuber	Cultivated	Fi, Hg	C: 5 Ma, 20 Mi; O: 1 Ma, 6 Ma
B) Food group – LEAFY VEGETABLES:							
Asam ruso (Mi)	Roselle	*Hibiscus sabdariffa* L.	Vegetable	Leaf	Cultivated	Hg	O: 0 Ma, 1 Mi
Bayam, Bayam liar (Mi); Siarum, Siarum liar (Ma)	Slim amaranth	*Amaranthus hybridus* L. (LP49)	Vegetable	Leaf, stem	Cultivated, wild	Fi, Hg, Af	C: 12 Ma, 30 Mi; O: 19 Ma, 15 Mi
Bayam merah (Mi)	Red amaranth	*Amaranthus hybridus* L. "Red variety" (LP50)	Vegetable	Leaf, stem	Cultivated	Hg	In data not dinstinguished from "Bayam"
Bayam angkik/duri (Mi, Ma)	Spiny amaranth	*Amaranthus* sp. (LP31)	Vegetable	Leaf, stem	Wild	Fi, Hg, Af	C: 1 Ma, 2 Mi
Bulung jepang (Ma)	Chayote (leaf)	*Sechium edule* (Jacq.) Sw.	Vegetable	Leaf, shoot	Cultivated, wild	Hg, Af	C: 3 Ma, 2 Mi; O: 7% Ma, 4% Mi
Daun papaya (Mi); Bulung botik (Ma)	Papaya (leaf)	*Carica papaya* L.	Vegetable	Leaf	Cultivated, wild	Fi, Hg, Af	C: 18 Ma, 30 Mi
Genjer (Mi); Kalanyoe (Ma)	Yellow burr head	*Limnocharis flava* (L.) Buchenau	Vegetable	Leaf, stem	Wild	Rf, Ae	C: 32 Ma, 28 Mi
Kagama (Mi)	Sessile joyweed	*Alternanthera sessilis* (L.) R.Br. ex DC. (LP34)	Vegetable	Leaf	Wild	Rf	Only FGD (Mi)

Kangkung (Mi, Ma); Kangkuang (Mi); Kengkong (Ma)	Water spinach	*Ipomoea aquatica* Forssk.	Vegetable	Leaf, stem	Cultivated	Hg, Rf, Fi	O: 8 Ma, 29 Mi
Kangkung air Kangkuang (Mi); Kengkong, Kangkung (Ma)	Water spinach (wild)	*Ipomoea aquatica* Forssk.	Vegetable	Leaf, stem	Wild	Ae, Rf	C: 73 Ma, 49 Mi
Katuk, Taruak manih (Mi); Nasi-nasi (Ma)	Sweet leaf	*Sauropus androgynus* (L.) Merr.	Vegetable	Leaf	Cultivated, wild	Af, Fi, Hg	C: 13 Ma, 7 Mi; O: 43% Ma, 9% Mi
Kelor (Mi); Barrunge (Ma)	Moringa	*Moringa oleifera* Lam. (LP22)	Vegetable	Leaf	Cultivated, wild	Hg, Fi	C: 10 Ma, 0 Mi; O: 7% Ma, 0% Mi
Komen, Koman (Ma)	Water mimosa	*Neptunia oleracea* Lour. (LP15)	Vegetable	Leaf, stem	Wild	Ae, Rf	C: 13 Ma, 0 Mi
Lobak kampung, Lobak local (Mi, Ma)	Yellowcress	*Rorippa indica* (L.) Hiern (LP30)	Vegetable	Leaf	Wild	Af, Fi	C: 3 Ma, 3 Mi
Lobak maniah (Mi)	Pak choi	*Brassica oleracea* var. chinensis (L.) Prain	Vegetable	Leaf	Cultivated	Hg	O: 2% Ma, 4% Mi
Lobak Pahiak (Mi)	Field mustard	*Brassica rapa* L.	Vegetable	Leaf	Cultivated	Hg	In data not dinstinguished from "Lobak maniah"
Lumai (Mi); Ranti (Ma)	Black nightshade	*Solanum americanum* Mill. (LP19)	Vegetable	Leaf, stem	Wild	Ag, Fi, Hg	C: 44 Ma, 32 Mi; O: 9 Ma, 4 Mi
Pahu (Mi); Pakis (Ma)	Vegetable fern	*Diplazium esculentum* (Retz.) Sw. (LP08)	Vegetable	Leaf	Wild	Fo, Ae	C: 69 Ma; 94 Mi
Pahu (Mi); Pakis hutan (Ma)	Tree fern	*Cyathea junghuhniana* (Kunze) Copel. (LP07)	Vegetable	Leaf	Wild	Fo	Only FGD (Ma)
Pina-Pina (Ma)	-	*Plukenetia corniculata Sm.* (LP14)	Vegetable	Leaf	Wild	Fi, Af	C: 6 Ma, 0 Mi
Pucuk jambak (Mi, Ma)	Rose apple (leaf)	*Syzygium* spp.	Vegetable	Leaf, shoot	Wild, cultivated	Ag, Hg	C: 0 Ma, 3 Mi O: 0% Ma, 8% Mi
Pucuk labu (Mi); Bulung jelok (Ma)	Pumpkin (leaf)	*Cucurbita moschata* Duchense	Vegetable	Leaf, shoot	Wild, cultivated	Af, Fi, Hg	C: 2 Ma, 1 Mi; O: 13 Ma, 7 Mi
Pucuk kacang tanah (Ma)	Peanut (leaf)	*Arachis hypogaea* L.	Vegetable	Leaf	Cultivated	Hg	Only FGD (Ma)
Pucuk ubi (Mi, Ma)	Cassava (leaf)	*Manihot esculenta* Crantz	Vegetable	Leaf	Wild, cultivated	Ag, Fi, Hg	C: 36 Ma, 41 Mi; O: 80% Ma, 78% Mi
Sawi, Sabi (Mi, Ma)	Choy sum	*Brassica* spp.	Vegetable	Leaf	Wild, cultivated	Af, Fi	C: 3 Ma, 3 Mi; O: 10 Ma, 1 Mi
Sayur asam (Ma)	Barrelier's woodsorrel	*Oxalis barrelieri* L. (LP26)	Vegetable	Leaf	Wild	Af, Fi	Only FGD (Ma)
Sayur paret, Selada sawah (Mi)	Watercress	*Nasturtium officinale* R.Br.	Vegetable	Leaf	Wild	Rf	C: 0 Ma, 3 Mi
Sijungkat (Ma)	Indian lettuce	*Lactuca indica* L. (LP23)	Vegetable	Leaf	Wild	Af, Fi	C: 4 Ma, 0 Mi
Simmange (Mi); Simmangah (Ma)	Water clover	*Marsilea quadrifolia* Hook. & Grev. (LP13)	Vegetable	Leaf	Wild	Rf	C: 1 Ma, 0 Mi

Sitopu (Mi, Ma); Daun manis (Ma)	-	*Claoxylon longifolium* (Blume) Endl. ex Hassk. (LP28)	Vegetable	Leaf	Wild, cultivated	Af	C: 6 Ma, 17 Mi; O: 2% Ma, 2% Mi
Tubo aie, Pegagan (Mi)	Java pennywort	*Hydrocotyle javanica* Thunb. (LP48)	Vegetable	Leaf	Wild	Rf	C: 0 Ma, 2 Mi
C) Food group – OTHER VEGETABLES:							
Asam belimbing (Mi, Ma); Belimbing besi (Mi)	Tree sorrel	*Averrhoa bilimbi* L.	Vegetable	Fruit	Cultivated, wild	Af, Hg	C: 0 Ma, 1 Mi; O: 0% Ma, 2% Mi
Batang/Taleh keladi (Mi); Keladi, Suhat (Ma)	Taro (stem)	*Colocasia* spp.	Vegetable	Stem	Cultivated, wild	Ae, Af	C: 0 Ma, 1 Mi; O: 1% Ma, 0% Mi
Batang/Taleh Kemumu (Mi)	Giant elephant ear (stem)	*Colocasia gigantea* (Blume) Hook.f. (LP39)	Vegetable	Stem	Wild	Af, Ae, Fi	C: 0 Ma, 1 Mi
Batang talas (Mi, Ma); Suhat (Ma)	Taro (stem)	*Colocasia esculenta* (L.) Schott (LP57)	Vegetable	Stem	Cultivated, wild	Ae, Af, Fi	C: 1 Ma, 5 Mi; O: 1% Ma, 10% Mi
Batang talas hitam (Mi)	Tania (stem)	*Xanthosoma sagittifolium* (L.) Schott (LP56)	Vegetable	Stem	Wild, cultivated	Ae, Af	C: 0 Ma, 1 Mi
Bawang merah (Mi, Ma)	Shallot	*Allium cepa* L.	Condiment	Tuber	Cultivated	Hg, Fi	O: 4% Ma, 0% Mi
Benkuang (Mi, Ma)	Jícama	*Pachyrhizus erosus* (L.) Urb. (LP03)	Vegetable	Tuber	Cultivated, wild	Af	C: 1 Ma, 0 Mi
Brokoli (Mi, Ma)	Broccoli	*Brassica oleracea* var. *italica* Plenck	Vegetable	Flower	Cultivated	Market	Market only
Buncis (Mi, Ma)	Green beans	*Phaseolus vulgaris* L.	Vegetable	Fruit	Cultivated	Hg, Rf	O: 3% Ma, 4% Mi
Bungo bawang (Mi); Bawang prei (Mi, Ma)	Welsch onion (flower)	*Allium fistulosum* L.	Vegetable	Leaf, flower	Cultivated	Hg, Rf	O: 15% Ma, 11% Mi
Bunga kol (Mi, Ma)	Cauliflower	*Brassica oleracea* var. *botrytis* L.	Vegetable	Flower	Market only	Market	Market only
Bunga papaya (Mi, Ma); Bunga botiak (Ma)	Papaya (flower)	*Carica papaya* L.	Vegetable	Fruit	Cultivated, wild	Af, Fi, Fo	Only FGD (Ma, Mi); O: 49% Ma, 26% Mi
Gundur (Mi, Ma); Kundua (Mi)	Wax gourd	*Benincasa hispida* (Thunb.) Cogn.	Vegetable	Fruit	Cultivated	Af, Hg	Only FGD (Ma, Mi)
Hunur (Ma)	-	*Artocarpus* sp.	Vegetable	Fruit	Wild	Ae, Af	C: 1 Ma, 0 Mi
Jantung pisang, Tukua pisang (Mi); Jattung pisang (Ma)	Banana (flower)	*Musa x paradisiaca* L., *Musa* sp.	Vegetable	Flower	Cultivated, wild	Af, Hg	C: 0 Ma, 2 Mi; O: 40% Ma, 54% Mi
Kacang belimbing (Mi); Kacang jorbing (Ma)	Winged bean	*Psophocarpus tetragonolobus* (L.) DC.	Vegetable	Fruit	Cultivated, wild	Af, Hg	C: 0 Ma, 1 Mi; O: 0% Ma, 1% Mi
Kacang Panjang (Mi, Ma)	Long bean	*Vigna unguiculata* subsp. *sesquipedalis* (L.) Verdc.	Vegetable	Fruit	Cultivated	Hg, Rf, Af	O: 13% Ma, 30% Mi
Kimcuang (Mi); Kimcong (Ma)	Torch ginger	*Etlingera elatior* (Jack) R.M.Sm. (LP02)	Vegetable	Flower	Wild	Af, Fo	C: 6 Ma, 51 Mi
Kol, Bunga kol (Mi, Ma)	Cabbage	*Brassica oleracea* var. *capitata* L.	Vegetable	Leaf	Cultivated	Market	Market only

Labu jepang (Mi); Bulung Jepang, Jepang (Ma)	Chayote	*Sechium edule* (Jacq.) Sw.	Vegetable	Fruit	Cultivated	Hg, Af	C: 3 Ma, 2 Mi; O: 7% Ma, 4% Mi
Lobak cino (Mi, Ma)	Daikon	*Raphanus sativus* var. *longipinnatus* L.H. Bailey	Vegetable	Root	Market only	Market	Market only
Naneh/Nenas mudo (Mi)	Pineapple (unripe)	*Ananas comosus* L. (Merr.)	Vegetable	Fruit (unripe)	Cultivated, wild	Af, Fi, Hg	O: 3% Ma, 16% Mi
Nangka mudo, Cubadak (Mi); Sibodak (Ma)	Jackfruit (unripe)	*Artocarpus heterophyllus* Lam.	Vegetable	Fruit (unripe)	Cultivated, wild	Ag, Fo	C: 3 Ma, 10 Mi; O: 4% Ma, 16% Mi
Paria/Pariyo/Pare liar (Mi); Paria, Paria-paria liar (Ma)	Bitter gourd (wild)	*Momordica charantia* L. (LP06)	Vegetable	Fruit	Wild	Af, Fi	C: 5 Ma, 14 Mi
Paria, Pariyo, Pare (Mi); Paria, Paria-paria (Ma)	Bitter gourd	*Momordica charantia* L.	Vegetable	Fruit	Cultivated	Af, Hg	O: 6% Ma, 14% Mi
Pariyo/Pio mancik (Mi)	Bitter gourd	*Momordica charantia* f. *abbreviata* (Ser.) W.J.de Wilde & Duyfjes (LP37)	Vegetable	Fruit	Wild	Af, Fi	C: 0 Ma, 4 Mi
Pepaya mudah (Mi, Ma)	Papaya (unripe)	*Carica papaya* L.	Vegetable	Fruit (unripe)	Cultivated, wild	Af, Fi, Hg	C: 1 Ma, 2 Mi; O: 49% Ma, 26% Mi
Petai cina (Mi, Ma)	Leucaena (pods)	*Leucaena leucocephala* (Lam.) de Wit	Vegetable	Fruit	Wild, cultivated	Af, Fi, Hg	C: 1 Ma, 0 Mi; O: 0% Ma, 2% Mi
Pira tobu, Tebu hitam (Ma)	Kans grass	*Saccharum spontaneum* L. (LP01)	Vegetable	Stem	Wild	Af, Fi	C: 1 Ma, 0 Mi
Pisang hutan (Ma)	Banana (wild)	*Musa acuminata* Colla	Vegetable	Stem	Wild	Fo	Only FGD (Ma)
Gambas, Pitulo (Mi, Ma)	Angled luffa	*Luffa acutangula* (L.) Roxb.	Vegetable	Fruit	Cultivated	Hg, Af	O: 4% Ma, 1% Mi
Pucuk rotan (Mi); Pangakt (Ma)	Rattan paku	*Calamus exilis* Griff. (LP24)	Vegetable	Shoot	Wild	Fo	C: 21 Ma, 1 Mi
Umbut puli (Ma)	-	*Arenga obtusifolia* Mart. (LP25)	Vegetable	Palm heart	Wild	Fo	C: 0 Ma, 2 Mi
Umbut sawit (Mi)	Oil palm (palm heart)	*Elaeis guineensis* Jacq.	Vegetable	Palm heart	Cultivated	Fi	Only FGD (Ma)
Umbut aren (Ma)	Sugar palm (palm heart)	*Arenga pinnata* (Wurmb) Merr.	Vegetable	Palm heart	Cultivated	Af	Only FGD (Ma)
Umbut kelapa (Mi)	Coconut (palm heart)	*Cocos nucifera* L.	Vegetable	Palm heart	Cultivated	Fi, Rf	O: 10% Ma, 24% Mi
Umbut baih/langkok (Mi)	-	Unidentified (Arecaceae)	Vegetable	Palm heart	Wild	Fo	C: 0 Ma, 2 Mi
Rabuang (Mi); Robung (Ma)	Common bamboo (shoot)	*Bambusa vulgaris* Schrad. (LP12)	Vegetable	Shoot	Wild	Af, Fo	C: 41 Ma, 71 Mi
Rebung batang (Mi)	Black bamboo (shoot)	*Gigantochloa atter* (Hassk.) Kurz (LP40)	Vegetable	Shoot	Wild	Af, Fo	In data not distinguished from "Rabuang"

Rimbang (Mi, Ma); Campur-campur (Ma)	Turkey berry	*Solanum torvum* Sw.	Vegetable	Fruit	Wild	Af, Fi, Hg	C: 31 Ma, 56 Mi
Selada (Mi, Ma)	Lettuce	*Lactuca sativa* L.	Vegetable	Leaf	Cultivated	Hg	O: 0% Ma, 1% Mi
Tabu-tabu (Mi)	Rattan manan	*Calamus manan* Miq. (LP38)	Vegetable	Shoot	Wild	Fo	Only FGD (Mi)
Timun (Mi, Ma)	Cucumber	*Cucumis sativus* L.	Vegetable	Fruit	Cultivated	Hg, Rf	O: 4% Ma, 3% Mi
Toge (Mi, Ma)	Mung bean (sprout)	*Vigna radiata* (L.) R.Wilczek	Vegetable	Shoot	Cultivated	Hg	O: 3% Ma, 2% Mi
Tomat (Mi, Ma)	Tomato	*Solanum lycopersicum* L.	Vegetable	Fruit	Cultivated	Hg	O: 14% Ma, 6% Mi
Torung asam (Mi, Ma)	Hairy-fruited eggplant	*Solanum lasiocarpum* Dunal (LP33)	Vegetable	Fruit	Wild, cultivated	Hg, Af	C: 1 Ma, 17 Mi; O: 1% Ma, 3% Mi
D) Food group – PULSES:							
Jariang (Mi); Joring (Ma); Jengkol (Mi, Ma)	Jengkol	*Archidendron pauciflorum* (Benth.) I.C.Nielsen	Vegetable	Seed	Cultivated, wild	Af	C: 4 Ma, 10 Mi; O: 9% Ma, 29% Mi
Kabau, Sikabau (Mi); Kaladeh (Ma)	-	*Archidendron bubalinum* (Jack) I.C.Nielsen	Vegetable	Seed	Cultivated, wild	Af	C: 0 Ma, 3 Mi
Kacang hijau (Mi, Ma)	Mung bean	*Vigna radiata* (L.) R.Wilczek	Seed	Seed	Cultivated	Hg	O: 3% Ma, 2% Mi
Kacang kayo (Mi)	Pigeon pea	*Cajanus cajan* (L.) Millsp. (LP42)	Seed	Seed	Cultivated	Af, Hg	O: 11% Ma, 0% Mi
Kacang merah (Mi, Ma)	Common bean	*Phaseolus vulgaris* L.	Seed	Seed	Cultivated	Market	Market only
Kacang parang (Mi)	Sword bean	*Canavalia gladiata* (Jacq.) DC. (LP54)	Seed	Seed	Cultivated	Hg, Af	Only FGD (Mi)
Kacang tujuh lembar daun (Mi)	-	Unidentified (Leguminosae) (LP41)	Seed	Seed	Cultivated, wild	Af, Fi	C: 0 Ma, 1 Mi
Kacang tunjuk (Mi, Ma)	Cowpea	*Vigna unguiculata* 'kacang tunjuk' (L.) Walp. (LP35)	Seed	Seed	Cultivated, wild	Fi, Hg	Only FGD (Mi, Ma)
Kacang kedelai (Mi); Kacang kuning (Ma)	Soy bean	*Glycine max* (L.) Merr.	Seed	Seed	Cultivated	Fi, Hg	O: 0% Ma, 2% Mi
Petai (Mi, Ma)	Stinky bean	*Parkia speciosa* Hassk.	Vegetable	Seed	Cultivated, wild	Af	C: 4 Ma, 3 Mi; O: 6% Ma, 12% Mi
Potar, Parira (Ma)	Stinky bean (wild)	*Parkia speciosa* Hassk. (LP17)	Vegetable	Seed	Wild	Af, Fo	C: 1 Ma, 0 Mi
E) Food group – NUTS AND SEEDS:							
Hunur (Ma)	-	*Artocarpus* sp.	Vegetable	Seed	Cultivated, wild	Af, Hg	C: 1 Ma, 0 Mi
Siwamang (Mi); Hapesong (Ma)	Pangi	*Pangium edule* Reinw.	Fruit	Seed	Cultivated, wild	Af	C: 0 Ma, 2 Mi
Melinjo (Mi, Ma)	Melinjo	*Gnetum gnemon* L. (LP53)	Fruit	Seed	Cultivated, wild	Af, Fi	Only FGD (Mi, Ma)
Tapuih (Mi)	-	*Elateriospermum tapos* Blume (LP43)	Fruit	Seed	Wild	Af, Fo	Only FGD (Mi)

F) Food group – VITAMIN A RICH PLANTS:							
Ambacang, Bacang, Macang (Mi); Ambacam (Ma)	Bachang	*Mangifera foetida* Lour.	Fruit	Fruit	Wild	Af, Fo	C: 10 Ma, 20 Mi
Kuini (Mi, Ma)	Kuwini	*Mangifera odorata* Griff.	Fruit	Fruit	Cultivated	Hg, Af	O: 4% Ma, 2% Mi
Labu (Mi); Jelok (Ma)	Pumpkin	*Cucurbita moschata* Duchense	Vegetable	Fruit	Cultivated	Af, Hg, Rf	O: 13 Ma, 7 Mi
Languang, Polam (Mi)	-	*Mangifera quadrifida* Jack (LP52)	Fruit	Fruit	Wild	Af, Fo	C: 0 Ma, 13 Mi
Latuik-latuik, Markisa Hutan (Mi, Ma); Rambutan akar (Mi); Sigambus (Ma)	Stinking passionflower	*Passiflora foetida* L. (LP29)	Fruit	Fruit	Wild	Af, Fi, Fo	C: 38 Ma, 44 Mi
Mangga (Mi, Ma)	Mango	*Mangifera indica* L.	Fruit	Fruit	Cultivated	Af, Hg, Rf	O: 13% Ma, 22% Mi
Markisa (Mi)	Passion fruit	*Passiflora edulis* Sims	Fruit	Fruit	Cultivated	Hg, Af	O: 0% Ma, 3% Mi
Pepaya (Mi); Botiak (Ma)	Papaya	*Carica papaya* L.	Fruit	Fruit	Cultivated, wild	Af, Fi, Hg	C: 22 Ma, 23 Mi; O: 49% Ma, 26% Mi
Polam, Ampalam (Mi); Manga harrangan, Manga kampung (Ma)	-	*Mangifera laurina* Blume (LP05)	Fruit	Fruit	Wild	Af, Fo	C: 2 Ma, 13 Mi
Wortel (Mi, Ma)	Carrot	*Daucus carota* L.	Vegetable	Root	Cultivated	Market	Market only

G) Food group – OTHER FRUITS							
Aia-aia (Mi)	Langsat	*Lansium parasiticum* (Osbeck) K.C.Sahni & Bennet (LP45)	Fruit	Fruit	Cultivated	Hg	O: 0% Ma, 1% Mi
Alpukat, Alpokat (Mi, Ma)	Avocado	*Persea americana* Mill.	Fruit	Fruit	Cultivated	Af	O: 22% Ma, 7% Mi
Anggur (Mi, Ma)	Grape	*Vitis vinifera* L.	Fruit	Fruit	Cultivated	Market	Market only
Apel (Mi, Ma)	Apple	*Malus domestica* Borkh.	Fruit	Fruit	Cultivated	Market	Market only
Belimbing manih (Mi); Belimbing (Ma)	Carambola	*Averrhoa carambola* L.	Fruit	Fruit	Cultivated	Af, Hg	O: 0% Ma, 2% Mi
Bonai, Limpanai (Mi)	-	Unidentified	Fruit	Fruit	Wild	Af, Fo	C: 0 Ma, 21 Mi
Buah lumai (Mi); Buah ranti (Ma)	Black nightshade (fruit)	*Solanum americanum* Mill. (LP19)	Fruit	Fruit	Wild	Af, Fi, Hg	C: 0 Ma, 2 Mi; O: 9% Ma, 4% Mi
Buah naga (Mi, Ma)	Dragon fruit	*Hylocereus undatus* (Haw.) Britton & Rose	Fruit	Fruit	Cultivated	Market	Market only
Buah rotan (Mi); Sihim (Ma)	Rattan (fruit)	*Calamus* spp.	Fruit	Fruit	Wild	Fo	C: 7 Ma, 4 Mi
Buah sery (Mi, Ma)	Calabura	*Muntingia calabura* L.	Fruit	Fruit	Cultivated	Hg	O: 0%, 4% Mi
Sorme (Mi, Ma)	Star gooseberry	*Phyllanthus acidus* (L.) Skeels (LP32)	Fruit	Fruit	Cultivated	Hg	Only FGD (Ma)
Cimparingek, Lancinek (Mi)	-	*Rubus buergeri* Miq. (LP61)	Fruit	Fruit	Wild	Af, Fo	C: 0 Ma, 12 Mi
Duku (Mi, Ma)	Langsat	*Lansium parasiticum* var. *duku* (Osbeck) K.C.Sahni & Bennet	Fruit	Fruit	Cultivated	Af	O: 12% Ma, 17% Mi

Durian (Mi, Ma); Tarutung (Ma)	Durian	*Durio zibethinus* L.	Fruit	Fruit	Cultivated	Af, Fo	O: 30% Ma, 71% Ma
Durian hutan, Durian mangko (Mi)	Durian (wild)	*Durio zibethinus* L., *Durio* sp. (LP59)	Fruit	Fruit	Wild	Fo	C: 38 Ma, 44 Mi
Garandan, Barandan (Mi)	-	*Lansium parasiticum* var. *garandan* (Osbeck) K.C.Sahni & Bennet (LP36)	Fruit	Fruit	Cultivated, wild	Af, Hg	C: 0 Ma, 2 Mi
Jambu bol (Mi, Ma); Jambak (Mi)	Malay apple	*Syzygium malaccense* (L.) Merr. & L.M.Perry	Fruit	Fruit	Cultivated	Af, Fo, Hg	O: 0% Ma, 8% Mi
Jambu air, Jambu madu (Mi); Jambu aek/aie (Ma)	Water apple	*Syzygium aqueum* (Burm.f.) Alston (LP04; LP55)	Fruit	Fruit	Cultivated, wild	Af, Fo, Hg	C: 10 Ma, 8 Mi; O: 11% Ma, 24% Mi
Jambu biji (Mi, Ma); Jambu paraweh (Mi); J. orsik (Ma)	Guava	*Psidium guajava* L.	Fruit	Fruit	Cultivated	Af, Fo, Hg	C: 20 Ma, 20 Mi; O: 5% Ma, 34% Mi
Jambu kaliang (Ma)	Java plum	*Syzygium cumini* (L.) Skeels	Fruit	Fruit	Cultivated	Hg	Only FGD (Ma)
Jeruk (Mi); Ute manis (Ma)	Orange	*Citrus sinensis* (L.) Osbeck	Fruit	Fruit	Cultivated	Af, Hg	O: 6% Ma, 23% Mi
Jeruk nipis (Mi, Ma)	Key lime	*Citrus aurantiifolia* (Christm.) Swingle	Fruit	Fruit	Cultivated	Af, Hg	O: 2% Ma, 4% Mi
Kapunduang (Mi, Ma)	Menteng	*Baccaurea racemosa* (Reinw. ex Blume) Müll.Arg. (LP11)	Fruit	Fruit	Cultivated, wild	Af, Fo	C: 37 Ma, 50 Mi; O: 0% Ma, 2% Mi
Karamunting (Mi); Haramunting (Ma)	Soapbush	*Clidemia hirta* (L.) D. Don (LP27)	Fruit	Fruit	Wild	Af, Fi, Fo	C: 7 Ma, 22 Mi
Kedongdong (Mi, Ma)	Golden apple	*Spondias dulcis* Parkinson	Fruit	Fruit	Cultivated, wild	Af, Fo	C: 10 Ma, 1 Mi; O: 2% Ma, 2% Mi
Kelapa (Mi, Ma)	Coconut	*Cocos nucifera* L.	Fruit	Fruit	Cultivated	Fi, Rf	O: 10% Ma, 24% Mi
Kolang-kaling (Mi, Ma)	Sugar palm (fruit)	*Arenga pinnata* (Wurmb) Merr.	Fruit	Fruit	Cultivated		Only FGD (Mi, Ma)
Kudaro (Mi)	-	*Hornstedtia conica* Ridl. (LP51)	Fruit	Fruit	Wild	Af, Fo	C: 0 Ma, 24 Mi
Langsek (Mi); Latcat, Langsat (Ma)	Langsat	*Lansium parasiticum* var. *domesticum* (Osbeck) K.C.Sahni & Bennet	Fruit	Fruit	Cultivated	Af	O: 12% Ma, 17% Mi
Ciplokan (Mi); Lapuik-lapuik (Ma)	Cutleaf ground cherry	*Physalis angulata* L. (LP62)	Fruit	Fruit	Wild	Af, Fi	C: 3 Ma, 1 Mi
Lengkeng (Mi, Ma); Kalengkeng (Mi)	Longan	*Dimocarpus longan* Lour.	Fruit	Fruit	Cultivated	Af	O: 3% Ma, 0% Mi
Manggis (Mi, Ma)	Mangosteen	*Garcinia* x *mangostana* L.	Fruit	Fruit	Cultivated	Af	O: 2% Ma, 37% Mi
Matoa (Mi, Ma)	Fijian longan	*Allophylus cobbe* (L.) Raeusch.	Fruit	Fruit	Cultivated	Hg	O: 2% Ma, 3% Mi
Melon (Mi, Ma)	Muskmelon	*Cucumis melo* L.	Fruit	Fruit	Cultivated	Market	Market only
Nangka (Mi, Ma)	Jackfruit	*Artocarpus heterophyllus* Lam.	Fruit	Fruit	Cultivated, wild	Ag, Fo	C: 3 Ma, 10 Mi; O: 4% Ma, 16% Mi
Nanas, Naneh (Mi); Onas (Ma)	Pineapple	*Ananas comosus* L. (Merr.)	Fruit	Fruit	Cultivated, wild	Af, Fi, Hg	C: 3 Ma, 2 Mi

Pir (Mi, Ma)	Pear	*Pyrus* spp.	Fruit	Fruit	Cultivated	Market	Market only
Pisang (Mi, Ma)	Banana	*Musa* x *paradisiaca* L.	Fruit	Fruit	Cultivated, wild	Af, Hg	C: 5 Ma, 6 Mi; O: 40% Ma, 54% Mi
Polesan (Mi)	Pulasan	*Nephelium mutabile* Blume (LP46)	Fruit	Fruit	Cultivated, wild	Af, Hg	C: 0 Ma, 4 Mi; O: 0% Ma, 2% Mi
Puah, Puahtok (Mi)	-	*Hornstedtia elongata* (Teijsm. & Binn.) K.Schum.	Fruit	Fruit	Wild	Af, Fo	C: 0 Ma, 20 Mi
Rambai, Rumbai (Mi); Rambe (Ma)	Rambai	*Baccaurea motleyana* (Müll.Arg.) Müll.Arg. (LP47)	Fruit	Fruit	Wild	Af, Fo	C: 9 Ma, 5 Mi
Rambutan (Mi, Ma)	Rambutan	*Nephelium lappaceum* L.	Fruit	Fruit	Cultivated	Af, Hg	O: 5% Ma, 14% Mi
Rambutan hutan, Rambutan liar (Mi)	Rambutan (wild)	*Nephelium lappaceum* L. (LP20)	Fruit	Fruit	Wild	Fo	C: 22 Ma, 15 Mi
Salak (Mi, Ma)	Snake fruit	*Salacca zalacca* (Gaertn.) Voss	Fruit	Fruit	Cultivated	Af	O: 2% Ma, 11% Mi
Salak lokal/liar (Mi, Ma)	Snake fruit (wild)	*Salacca sumatrana* Becc.	Fruit	Fruit	Cultivated, wild	Af, Fo	C: 6 Ma, 14 Mi
Sawo (Mi, Ma); Saos (Mi); Sawu (Ma)	Sapodilla	*Manilkara zapota* (L.) P.Royen	Fruit	Fruit	Cultivated	Af, Hg	O: 5% Ma, 7% Mi
Semangka (Mi, Ma)	Watermelon	*Citrullus lanatus* (Thunb.) Matsum. & Nakai	Fruit	Fruit	Cultivated	Market	Market only
Sikaduduak (Mi); Sikaduduk (Ma)	Malabar melastome	*Melastoma malabathricum* L. (LP18)	Fruit	Fruit	Wild	Af, Fi, Fo	C: 3 Ma, 12 Mi
Sinasi, Nasi-nasi (Mi)	-	*Callicarpa arborea* Roxb. (LP60)	Fruit	Fruit	Wild	Ag, Fi	C: 0 Ma, 1 Mi
Sirsak (Mi, Ma); Durian belanda (Mi); Tarutung belanda (Ma)	Soursop	*Annona muricata* L.	Fruit	Fruit	Cultivated	Af, Hg	O: 4% Ma, 26% Mi
Srikaya, Buah nona (Mi)	Sugar apple	*Annona squamosa* L.	Fruit	Fruit	Cultivated	Hg	O: 0% Ma, 2% Mi
Strobery (Mi, Ma)	Strawberry	*Fragaria* x *ananassa* (Weston) Duchesne	Fruit	Fruit	Cultivated	Market	Market only
Tabu, Tebu (Mi, Ma)	Sugarcane	*Saccharum officinarum* L.	Fruit	Stem	Cultivated	Af, Hg	O: 2% Ma, 7% Mi
Tarok (Mi); Torop (Ma)	Terap	*Artocarpus elasticus* Reinw. ex Blume (LP21)	Fruit	Fruit	Wild	Af, Fo	C: 3 Ma, 7 Mi
Ukam, Rukam (Mi)	Rukam	*Flacourtia rukam* Zoll. & Moritzi (LP44)	Fruit	Fruit	Wild	Af, Fo	C: 3 Ma, 22 Mi

[1] Mi – Minangkabau language, Ma – Mandailing language

[2] Ae – aquatic environments, Af – agroforestry, Fi – fields/fallows, Fo – forests, Hg – homegardens, Rf – rice fields. Mi – Minangkabau

[3] Citations – number of citations of wild food plants based on individual freelisting, Occurrence – frequency (%) of occurrence of food crops (at species level) cultivated by individual household

Appendix 2: Applied intervention for knowledge sharing and awareness raising

Events conducted for knowledge sharing and awareness raising

Food, Nutrition, and Ethnobotany workshop at Bogor Agricultural University, Java

On 22. 1. 2018, a capacity building workshop on Food, Nutrition, and Ethnobotany was organized by the study author and IPB University assistants (Fig. A1). The workshop was held at the Department of Community Nutrition in IPB University, and it was attended by 25 participants from 5 institutions (IPB University, Department of Community Nutrition; IPB University – Department of Forest Resources Conservation and Ecotourism, CIFOR, Slowfood Indonesia, Czech University of Life Sciences Prague). A total of 6 presentations focusing on methods and results related to ethnobotany, nutrition and food systems were presented. All the workshop participants obtained a certificate of workshop participation (and speakers of presentation).

Figure A1 Photo from the workshop organized by the study and held at IPB University

Conducting final workshop for government and academia of Padang in West Sumatra

On 7. 12. 2018, the final policy-academic workshop was held at the Andalas University in Padang (Fig. A2). The workshop was organized for academicians, students and the provincial government of Padang. Prof. Indrawaty Lipoeto facilitated the workshop. Among the presenters were a staff of the Ministry of Health of West Sumatra, who presented the nutritional situation and strategy in West Sumatra. Study partners from the Community Nutrition of IPB University (Prof. Ali Khomsan, and assistant Utami Wahyuningsih) presented the key results of the FAD project combined with nutritional recommendations. Prof. Ervizal AM Zuhud - the study partner from the Faculty of Forestry at IPB University, presented the importance of forests and agroforests for livelihood and culture. The principal investigator Lukas Pawera overviewed the study and its results and provided recommendations to governments and researchers for further research, programs and actions. Each present ministry and key stakeholders obtained the community poster, guidebook, and policy brief developed by the study. Twenty-three participants attended the Padang workshop. All the participants received a certificate.

Figure A2 A group photo from the workshop in Padang

Final workshops and traditional food competitions for the studied communities

On 9. 12. 2018, the final workshop for the Mandailing community was conducted in Sontang village, Padang Gelugur sub-district, Pasaman district (Fig. A3). Then on Monday 10. December, the second community workshop for the Minangkabau farmers was conducted in Alahan Mati village, Simpang Alahan Mati sub-district of Pasaman district (Fig. A4). The workshops were opened by the head of the villages or local government representatives. It was followed by a speech of the principal investigator Lukas Pawera who overviewed the study and its results. Further, the professors from IPB University (Prof. Ali Khomsan, Prof. Ervizal AM Zuhud) and Andalas University (Prof. Nur Indrawaty Lipoeto) provided nutrition and health-related suggestion to the communities. The event was accompanied by a traditional food competition, where the local women groups brought and presented traditional foods and fresh samples of fruits and vegetables. The foods and crop diversity were evaluated by the juries (study team and assistants), and 9 different price categories were announced and judged. The boxes with prices containing cooking utensils were distributed to the winners along with the certificates. For the cocoa male farmers, there was also 1 price category for the best cocoa fruit. All the previous respondents from the survey and also the workshop participants were given the community book, and illustrations showing agroforestry cocoa farm and traditional rice field created by the study. Head of the villages and governmental officers were also given the policy brief. The community posters were provided to each farmer/women group.

Figure A3 Mandailing women presenting traditional food to the committee of Prof. Khomsan, Prof. Lipoeto, Prof. Zuhud, assistant Ms Utami and Swisscontact staff in Sontang village

Figure A4 Minangkabau community with local government and project team during the workshop and food competition in Alahan Mati village

Communication materials developed for the local communities and governments

Community poster

The study has identified nutrient-rich local food plants, which were promoted to increase dietary diversity and nutrient intake. In the poster, special reference was paid to plants rich in iron, vitamin A, protein, and vitamin C. Those nutrients' deficiencies were also directly illustrated in the poster (see the poster in Fig. A5).

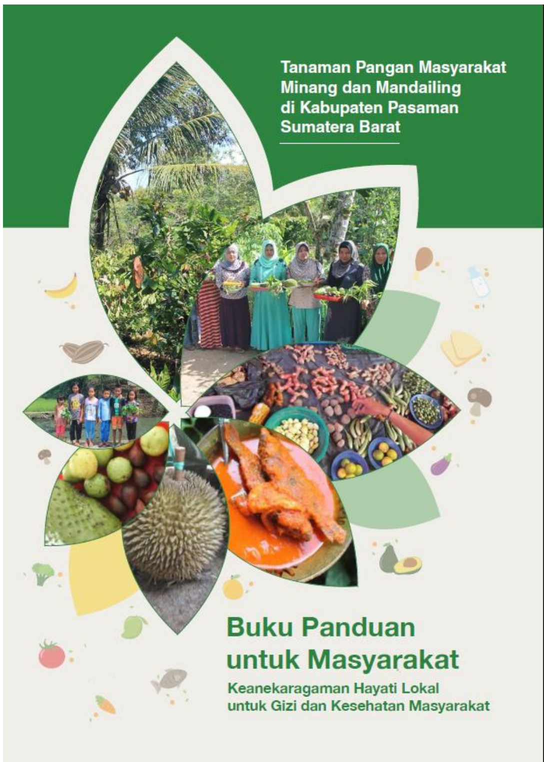
Figure A5 Community poster produced by the study

Community guidebook

The main material produced for the communities was a guidebook that included recommendations for diet and health. It includes information on the nutrition and health benefits of the documented local food plants (Pawera et al. 2018). The community book also explains how to tackle malnutrition, anaemia, obesity, hypertension, diabetes and the most common health disorders in the studied area. The agrobiodiversity conservation and farm diversification were also addressed. Colourful pictures and illustrations enriched the book, and it also includes motivating quotations related to food biodiversity from the researchers, key respondents, and community leaders. As the communities can speak the Indonesian language, the book used Bahasa Indonesia, but the local plant names were given in Minangkabau and Mandailing languages. Raising awareness at the community level through the community materials is expected to change the behaviour and improve the diet, nutrition, health while conserving agrobiodiversity. The cover page of the guidebook can be seen in Fig. A6. The guidebook was strongly aligned with the national dietary guidelines (MOH 2014).

Policy brief for the government

The last type of material developed was the policy brief, where the key messages and recommendations for the governments were summarized (see the cover page in Fig. A7).



Risalah Kebijakan 2018

Potensi Tanaman Pangan Lokal untuk Perbaikan Gizi Masyarakat

Ringkasan Eksekutif

Konsumsi pangan di perdesaan di Indonesia termasuk di Pasaman masih kurang dalam hal keberagaman, sementara itu sayuran dan buah lokal sebenarnya cukup tersedia dan dapat dimanfaatkan untuk meningkatkan gizi dan kesehatan masyarakat. Pemanfaatan tanaman lokal yang kaya gizi sebagai upaya perwujudan pola pangan dengan gizi seimbang adalah investasi gizi yang bukan hanya bersifat efektif dari segi biaya (*cost-effective)*, melainkan juga dapat bertahan lama, lestari, dan memilik rasio manfaat-biaya *(benefit-cost ratio)* yang baik. Perbaikan gizi dan kesehatan masyarakat dengan pemanfaatan tanaman lokal adalah solusi yang bersifat *win-win solution* karena menggabungkan unsur konservasi dan pembangunan. Meningkatkan kesadaran masyarakat dan membangun kapasitas petani-petani kecil untuk memproduksi pangan dari tanaman lokal serta menghubungkannya ke pasar, sekolah, atau restoran dapat mendorong perbaikan di bidang pendidikan dan produktivitas masyarakat sehingga akhirnya dapat memperbaiki pertumbuhan sosial-ekonomi.

Apa itu keanekaragaman hayati tanaman pangan dan makanan tradisional dan mengapa penting?

Keragaman tanaman pangan, pangan hewani serta organisme lain - baik yang dibudidayakan atau diperoleh secara liar – dapat menjadi sousi untuk mengurangi malnutrisi dan memperbaiki kualitas hidup masyarakat. Indonesia memiliki beragam keragaman spesies-spesies pangan seperti: tanaman pangan liar, ternak lokal, dan tanaman-tanaman pangan lainnya yang bergizi. Termasuk di antaranya adalah sayuran hijau, kacang-kacangan, dan buah yang kaya gizi seperti vitamin A dan zat besi. Meski ketersediaannya berlimpah, namun seringkali pangan-pangan tersebut tidak dimanfaatkan secara optimal karena keterbatasan informasi mengenai kandungan gizi dan belum disadari manfaatnya untuk kesehatan. Keunikan keanekaragaman hayati pangan Indonesia akhirnya hilang dan tidak termanfaatkan. Peningkatan produksi pangan-pangan ini dan bangkitnya kesadaran tentang pentingnya membuka pasar tentu akan bermanfaat untuk perbaikan pendapatan keluarga, dan di sisi lain akan mendukung pembangunan desa dan menjaga lingkungan. Peningkatan keanekaragaman hayati pangan dalam sistem pangan Indonesia akan memberi keuntungan jangka panjang dan membantu meraih sasaran ataupun tujuan baik di level nasional atau internasional.

Figure A6 Cover page of the community book **Figure A7** Cover page of the policy brief

Below is the complete list of individuals or institutions who obtained the study materials (Community guidebook and/or poster and/or policy brief):

1. Minangkabau and Mandailing study participants (200 direct beneficiaries from 4 villages)
2. Dinas Kesehatan Sumatera Barat (Ministry of Health, Padang, West Sumatra)
3. Dinas Pertanian Sumatera Barat (Ministry of Agriculture, Padang, West Sumatra)
4. Dinas Ketehanan Pangan Sumatera Barat (Ministry of Food Security, Padang)
5. Dinas Kesehatan Pasaman (Ministry of Health, Lubuk Sikaping, Pasaman)
6. Dinas Ketehanan Pangan Pasaman (Ministry of Food Security, Lubuk Sikaping, Pasaman)
7. Dinas Pertanian Pasaman (Ministry of Agriculture, Lubuk Sikaping, Pasaman)
8. Dinas Pertanian Penyuluh Pasaman (Ministry of Agri. Extension, Lubuk Sikaping, Pasaman)
9. Dinas Pendidikan dan Kebudayaan Pasaman (Min. of Education/Culture, Lubuk Sikaping, P.)
10. Dinas Kehutanan Pasaman (Ministry of Forestry, Lubuk Sikaping, Pasaman)
11. Posyandu Pasaman (Community Health Worker Center, Simpang Alahan Mati sub-district)
12. Universitas Andalas, Fakultas kedokteran (Andalas Universit, Faculty of Medicine, Padang)
13. Universitas Andalas, Fakultas pertanian (Andalas University, Faculty of Agriculture, Padang)
14. Universitas Andalas, Fakultas biology (Andalas University, Faculty of Biology, Padang)
15. IPB Bogor, Fakultas Ekologi Manusia (IPB University, Faculty of Human Ecology, Bogor)
16. IPB Bogor, Fakultas Kehutanan (IPB University, Faculty of Forestry, Bogor)
17. Swisscontact Indonesia (West Sumatra and Jakarta)
18. Surfaid NGO (Mentawai)

Appendix 3: Examples of behaviour change illustrations developed for the communities

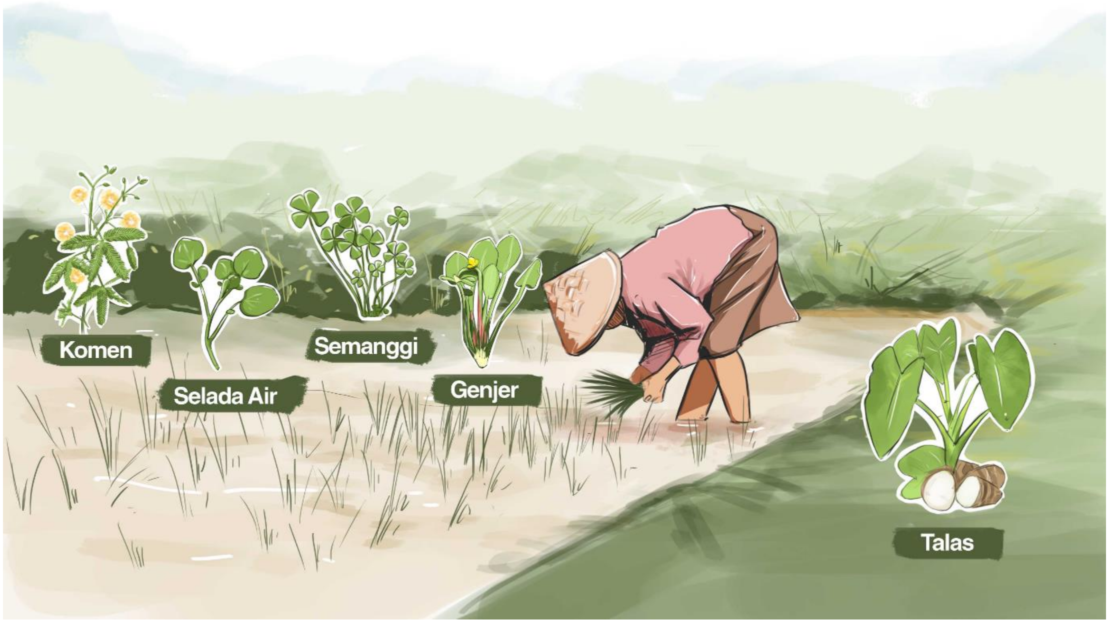


Fig. Illustration demonstrating that wild aquatic vegetables are part of traditional rice field (adapted from the community guidebook by Pawera et al. 2018)

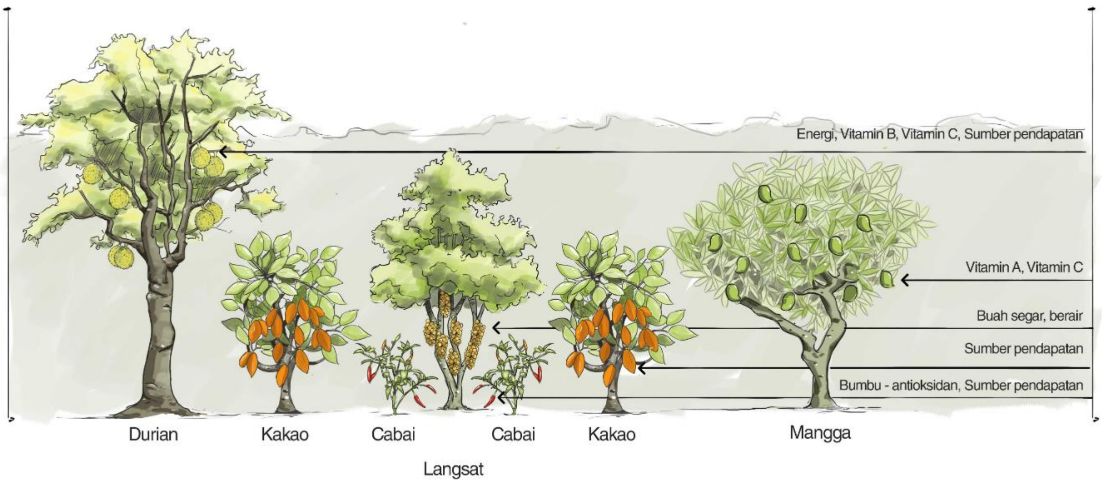


Fig. Illustration demonstrating nutritional importance of fruit trees in local cocoa agroforestry systems (adapted from the community guidebook by Pawera et al. 2018)

Appendix 4: Timeline of the study activities in Indonesia

Year 2018	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Research permits and preparations in Jakarta	✓											
Team meetings and preparations in Bogor		✓										
Team meetings and preparations in Padang		✓	✓									
Main data collection in Pasaman			✓	✓	✓							
Additional fieldwork (plant specimens)							✓					
Initial data analysis and development of community materials								✓	✓	✓	✓	✓
Final academic/policy workshop in Padang												✓
Final community workshops and traditional food competitions in Pasaman												✓

- Preparations in Jakarta starts on 1.1.2018 and ends on 31.1.2018
- Preparations in Bogor (at IPB Bogor) starts on 1.2.2018 and ends on 26.2. 2018
- Preparations in Padang (at Andalas University) starts on 27.2.2018 and ends on 17.3.2018
- Continuous fieldwork in Pasaman regency starts on 18.3.2018 and ends on 28.5.2018
- A short additional fieldwork in Pasaman regency to collect missing plant specimens, followed by the plant identification at Andalas University in Padang from 3.7.2018 to 11.7.2018
- Initial data analysis and development of community materials within August-December 2018
- The results-sharing academic/policy workshop at Andalas University in Padang happens on 7.12.2018
- The closing community workshops and traditional food competitions in Pasaman regency happens on 9.12.2018 in Mandailing area (Sontang village), and 10.12.2018 in Minangkabau area (Simpang village).

Appendix 5: List of publications, manuscripts and conference contributions based on the doctoral study

Published research articles

Pawera L, Khomsan A, Zuhud EAM, Hunter D, Ickowitz A, Polesny Z. 2020. Wild food plants and trends in their use: From knowledge and perceptions to drivers of change in West Sumatra. Foods **9** (9): 1240.

Borelli T, Hunter D, Powell B, Ulian.T, Mattana E, Termote C, **Pawera L**, Beltrame D, Penafiel D, Tan A, Taylor M, Engels MMJ. 2020. Born to eat wild: an integrated conservation approach to secure wild food plants for food security and nutrition. Plants **9** (10): 1299.

Research articles in preparation

Pawera L, Khomsan A, Zuhud EAM, Hunter D, Termote C, Polesny Z. Linking biodiversity with nutrition: New indices for quantifying importance, underutilization and potential of agrobiodiversity for dietary diversity (Manuscript to Global Food Security/Food security).

Pawera L, Khomsan A, Hunter D, Termote C, Polesny Z. Agrobiodiversity, markets and diets. Tracing nutrients and food acquisition pathways in rural tropical food environment (Manuscript to Public Health Nutrition/Food Policy).

Conferences and seminars

Pawera L, Polesny Z, Hunter D, Termote C. 2020. Dietary diversity but from what kind of foods? Incorporating food processing into dietary diversity indicators. Agriculture, Nutrition, and Health Academy Week, 30. 6 - 2. 7. 2020, online (video presentation).

Pawera L, Khomsan A, Zuhud EAM, Lipoeto N, Polesny Z, Hunter D. 2019. Developing new quantitative indices for assessing the potential of edible species for dietary diversity. Agriculture, Nutrition and Health Academy Week, 24-28. 6. 2019, Hyderabad, India (oral presentation).

Pawera L. 2018. Linking Ethnobiology with Nutrition: Methods, Approaches, and Way Forward. Workshop on Food, Nutrition, and Ethnobotany, 22. 1. 2018, Bogor, Indonesia (oral presentation).

Appendix 6: *Photos from the data collection*

Fig. Discussing Minang food plants with farmers

Fig. Market observation in Minang area

Fig. Ms. Yesti interviewing Mandailing woman

Fig. Ms. Ayi interviewing Minang woman

Fig. Facilitator conducting seasonal calendar

Fig. Team conducting 4-cell method

Fig. Minangkabau women with food plants

Fig. Mandailing people with food plants

Appendix 7: *Photos of the local land-uses and landscape*

Fig. Rice field in Simpang village

Fig. Rice terraces in Alahan Mati village

Fig. Homegarden in Simpang village

Fig. Bamboo in forest of Sontang village

Fig. Fishermen at river in Simpang village

Fig. Water mimosa in pond in Sontang village

Fig. Cocoa farm in Simpang village

Fig. Durian tree over cocoa in Sontang village

Appendix 8: *Photos from the traditional food competitions and community workshops*

Fig. Mandailing traditional foods

Fig. Minangkabau traditional foods

Fig. Mandailing food plants

Fig. Minangkabau food plant diversity

Fig. Launch of workshop for Mandailings

Fig. Officer launching workshop for Minangs

Fig. Minang women with produced materials

Fig. Mandailing women receiving materials

Appendix 9: *Photos of selected less common food plants*

Fig. Fruit of nut *Elateriospermum tapos*

Fig. Fruit and seeds of *Artocarpus* sp.

Fig. Unripe fruit of *Nephelium mutabile*

Fig. Fruit of *Hornstendtia conica*

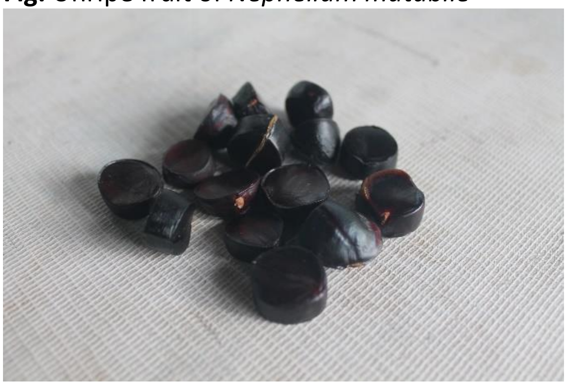


Fig. Seed of legume *Archidendron bubalinum*

Fig. Pod of bean "Kacang tujuh lembar daun"

Fig. Leaves of *Claoxylon longifolium*

Fig. Leaves of *Pluketenia corniculata*

Appendix 10: *Author's Curriculum Vitae*

Name: Ing. Lukáš Pawera

Nationality: Czech Republic

Date of born: 20 May 1988

Address: Borek 47, 534 01 Holice v Čechách

Phone: +420721386315

Email: paweralukas@gmail.com

EDUCATION:

PhD in Tropical Agrobiology and Bioresource Management - Czech University of Life Sciences Prague (2016 – 2021*anticipated)

MSc in Tropical Crop Management and Ecology (with distinction) - Czech University of Life Sciences Prague (2011 - 2014)

BSc in Agriculture of Tropics and Subtropics - Czech University of Life Sciences Prague (2008 - 2011)

WORK EXPERIENCE:

Center for International Forestry Research (CIFOR) – Consultant for the Sustainable Landscape and Livelihoods Team

- Data analysis and publication development - Dietary patterns among Dayak women across the forest transition in Borneo (3/03/2021 – ongoing; home-based)

Alliance of Bioversity International and CIAT - Consultant expert on socioeconomy and biodiversity

- Contribution to the preparation of GEF project (PPG phase) – Crop diversity conservation for sustainable use in Indonesia (8/02/2021 – ongoing; home-based)

Alliance of Bioversity International and CIAT - Consultant specialist for the Indigenous Partnership

- Development of food system learning platform (27/07/2020 – 15/10/2020; home-based)

Bioversity International - Consultant for the Indigenous Partnership

- Improving the Indigenous fellowship training programme (03/02/2020 – 07/02/2020; Rome)

Bioversity International - Consultant for the Indigenous Partnership

- Operationalizing barrier analysis and landscape resilience tools (14/10/2019 – 07/11/2019; India, Thailand, Indonesia)

Bioversity International - Consultant for the Indigenous Partnership

- Indigenous Fellowship programme specialist (22/05/2019 – 17/07/2019, Rome)

Bioversity International - Research fellow at the Indigenous Partnership

- Survey of dietary diversity and agrobiodiversity (07/01/2019 – 15/03/2019; Shillong, India)

Project Principal Investigator - funded by Neys-Van Hoogstraten Foundation and Erasmus Mundus ALFABET

- Food, Agrobiodiversity and Diet project in West Sumatra (01/01/2018 – 31/12/2018; Jakarta and Padang, Indonesia)

Alliance of Indigenous Peoples of the Indonesian Archipelago (AMAN) - Trainer

- Training on monitoring of food systems (01/07/2018 – 14/07/2018; Jakarta, Indonesia)

Bioversity International - Research fellow at the Platform for Agrobiodiversity Research (PAR)

- Contribution to the development of method book – Assessing Agrobiodiversity: A Compendium of Methods (22/02/2018 – 21/03/2018; home-based)

Bioversity International - Intern at the Healthy Diets from Sustainable Food Systems Initiative

- Support of UNEP-GEF funded Biodiversity for Food and Nutrition (BFN) project and PhD project proposal development (01/08/2017 – 30/09/2017; Rome, Italy)

Swisscontact Indonesia - Intern at Research and Development Unit

- Support of Good Nutrition Practices Project, a Component of Sustainable Cocoa Production Program (01/11/2015 – 30/06/2016; Makassar, Indonesia)

People in Need - Intern in project monitoring and reporting

- Monitoring and reporting of agricultural, livelihood and environment projects (15/01/2015 – 07/03/2015; Hawassa, Ethiopia)

Hawassa University - Volunteer for Vondo Genet College of Forestry and Natural Resource

- Assistance in arboretum and herbarium (17/10/2014 – 18/11/2014; Hawassa, Ethiopia)

Research Institute for Fodder Crops – Partime assignments

- Assistance with the collection of plant genetic resources (crop wild relatives) (15/06/2014 – 30/08/2014; Troubsko, Czech Republic)

Atregia - Partime job

- Inventory and assessment of trees (1/4/2014 – 30/6/2014; Hradec Kralove, Czech Republic)

Lomza Landscape Park - Erasmus traineeship

- Landscape park maintenance and botanical mapping (1/6/2013 – 30/9/2013; Lomza, Poland)

PEER-REVIEWED RESEARCH ARTICLES:

Borelli T, Hunter D, Powell B, UlianT, Mattana E, Termote C, **Pawera L**, Beltrame D, Penafiel D, Tan A, Taylor M, Engels MMJ. 2020. Born to eat wild: an integrated conservation approach to secure wild food plants for food security and nutrition. Plants **9** (10): 1299.

Pawera L, Khomsan A, Zuhud EAM, Hunter D, Ickowitz A, Polesny Z. 2020. Wild food plants and trends in their use: From knowledge and perceptions to drivers of change in West Sumatra. Foods **9** (9): 1240.

Nurhasan M, **Pawera L**, Lo M, Pratama MF, Rahmah M, Mustika MHU, Rowland D. 2020. Commentary: Oil Palm Boom and Household Diets in the Tropics. Frontiers in Sustainable Food Systems **4**: 39.

Reátegui CR, **Pawera L**, Panduro VPP, Polesny Z. 2018. Beetles, ants, wasps, or flies? An ethnobiological study of edible insects among the Awajún Amerindians in Amazonas, Peru. Journal of Ethnobiology and Ethnomedicine **14**: 53.

Reimers E, Cusimamani E, Rodriguez E, Zepeda del Valle J, Polesny Z, **Pawera L**. 2018. An ethnobotanical study of medicinal plants used in Zacatecas state, Mexico. Acta Societatis Botanicorum Poloniae: **87** (2): 3581.

Pawera L, Luczaj L, Pieroni A, Polesny Z. 2017. Traditional plant knowledge in the White Carpathians: Ethnobotany of wild food plants and crop wild relatives in the Czech Republic. Human Ecology **45** (5): 655-671.

Pawera L, Verner V, Termote C, Kandakov A, Karabaev NA, Polesny Z. 2016. Medical ethnobotany of herbal practitioners in the Turkestan Range, southern Kyrgyzstan. Acta Societatis Botanicorum Poloniae **85** (1): 3483.

Vlkova M, Verner V, Kandakov A, Polesny Z, Karabaev N, **Pawera L**, Nadvornikova I, Banout J. 2015. Edible plants sold on marginal rural markets in Fergana Valley, southern Kyrgyzstan. Bulgarian Journal of Agricultural Sciences **21**: 243–250.

BOOK CHAPTERS:

Mawroh B, **Pawera L**, Lyngdoh S, Nongrum S (accepted) Shifting cultivation as an important source of food biodiversity for dietary diversity. In Cairns M (Ed) Farmer Innovations and Best Practices by Shifting Cultivators in Asia-Pacific. CABI Publishing.

Lojka B, **Pawera L**, Kalousová M, Bortl L, Verner V, Houška J, Vanhove W, Van Damme P. 2017. Multistrata Systems: Potentials and Challenges of Cocoa-based Agroforests in the Humid

Tropics. In: Dagar CHJ and Tewari PV (eds.) Agroforestry Anectodal to Modern Science. Springer, Singapore, pp 587-628.

Pieroni A, **Pawera L**, Shah GM. 2016. Gastronomic ethnobiology. In: Albuquerque UP, Nóbrega A, Romulo R (eds.) Introduction to ethnobiology. Springer, New York, pp 53-62.

METHOD BOOKS AND GUIDELINES:

PAR. 2018. Assessing Agrobiodiversity: A Compendium of Methods. Platform for Agrobiodiversity Research, Rome.

Pawera L, Khomsan A, Zuhud EAM, Lipoeto N. 2018. Food plants of Minangkabau and Mandailing cocoa farmers in Pasaman district, West Sumatra, Indonesia. Biodiversity for nutrition and health - Community guidebook. Swisscontact, Jakarta. (Indonesian language)

Pawera L, Polesny Z. 2015. Potential of agrobiodiversity and traditional knowledge to combat hidden hunger. Development goal 2: Food security in development projects: A handbook of implementation of foreign development cooperation of Czech Republic. Czech University of Life Sciences Prague Press, pp 6- 35. (Czech language)

Swisscontact Indonesia. 2016. Good Nutrition Practices (GNP). Swisscontact training manual, pp. 32. (Indonesian language)

CONFERENCES AND SEMINARS:

Pawera L, Polesny Z, Hunter D, Termote C. 2020. Dietary diversity but from what kind of foods? Incorporating food processing into dietary diversity indicators. Agriculture, Nutrition, and Health Academy Week, 30. 6 - 2. 7. 2020, online (video presentation).

Thwe SM, **Pawera L**, Whitney C, Polesny Z. 2019. Agrobiodiversity of Homegardens in Pyay District, Myanmar. Tropentag, 18-20. 9. 2019, Kassel, Germany (oral).

Tasev M, Carbonó E, **Pawera L**, Whitney C, Verner V, Polesny Z. 2019. Urban Ethnobotany: Medicinal Plants Used for the Treatment of Noncommunicable Diseases in Santa Marta, Colombia. Tropentag, 18-20. 9. 2019, Kassel, Germany (poster).

Pawera L and Mawroh B. 2019. Profiling Indigenous Food Systems (IFS) Context and methods. Seminar on matriarchal indigenous food systems, 10.7. 2019, FAO, Rome, Italy (oral).

Pawera L, Khomsan A, Zuhud EAM, Lipoeto N, Polesny Z, Hunter D. 2019. Developing new quantitative indices for assessing thepotential of edible species for dietary diversity. Agriculture, Nutrition and Health Academy Week, 24-28. 6. 2019, Hyderabad, India (oral).

Pawera L. 2018. Linking Ethnobiology with Nutrition: Methods, Approaches, and Way Forward. Workshop on Food, Nutrition, and Ethnobotany, 22.1.2018, Bogor, Indonesia (oral).

Pawera L, Tumova B, Termote C, Polesny Z, Hunter D. 2017. Diversity of edible plants in food systems of Bugis, Mandar, Minang, and Acehnese cocoa farmers in Indonesia. 58th Annual Meeting of the Society for Economic Botany, 4-9. 6. 2017, Braganca, Portugal (oral).

Purba ECH, **Pawera L**, Nisyawati, Silalahi M. 2017. Gastronomic ethnobiology of Terites: indigenous food specialty of Batak Karo people in North Sumatra, Indonesia. 58th Meeting of the Society for Economic Botany, 4-9. 6. 2017, Braganca, Portugal (poster).

Pawera L, Luczaj L, Polesny Z. 2017. Could bio-cultural refugia safeguard important reservoirs of traditional plant knowledge in highly industrialized countries? A case study of the White Carpathians, Czech Republic. 58th Annual Meeting of the Society for Economic Botany, 4-9. 6. 2017, Braganca, Portugal (poster).

Pawera L. 2017. White Carpathians as a bio-cultural hotspot of the Czech Republic? Ethnoecological workshop, 20-21. 4. 2017, Nitra, Slovakia (oral).

Pawera L, Tumova B, Hunter D. 2017. Survey of local food plants and dietary diversity of smallscale cocoa farmers in Sulawesi and Sumatra and its implications for a large-scale nutrition project. Symposium of Biodiversity and Wild Edible Species, 3-5. 4. 2017, Antalya, Turkey (oral).

Pawera L, Polesny Z. 2016. Ethnomycology of White Carpathians. Ethnobiology workshop, 3-4. 12. 2016, Wroclaw, Poland (oral).

Pawera L, Polesny Z. 2016. Neglected potential of agrobiodiversity and traditional knowledge to combat hidden hunger. Tropical Biodiversity Conservation Conference, 8-9. 11. 2016, Prague, Czech Republic (keynote speech).

Pawera L. 2013. Traditional uses of medicinal and wild edible plants in White Carpathians. 3rd workshop of Eastern European Ethnobiology, 9-13. 10. 2013, Rzeszow, Poland (oral).

Pawera L, Polesny Z, Verner V, Sodombekov IS, Kandakov A, Karabaev NA. 2013. Medicinal plants used in Turkestan Range (Leilek District, Western Kyrgyzstan). 7th Scientific Conference of the Faculty of Tropical AgriSciences, 28. 11. 2013, Prague, Czech Republic (oral).

MEMBERSHIP IN SOCIETIES OR EXPERT GROUPS:

Society for Economic Botany (student representative-elect and upcoming student president)

FAO Global Hub on Indigenous Food Systems (expert member)

SIANI (member and expert)

Agriculture, Nutrition and Health (ANH/IMMANA) community (member)

YPARD (member)

NESFAS Task Force on Malnutrition in North-East India (committee member)

EDITORIAL AND REVIEW SERVICES:

Editorial board: Ethnobotany Research and Applications

A reviewer: Frontiers in Sustainable Food Systems, Ecology of Food and Nutrition, Journal of Ethnobiology and Ethnomedicine, Human Ecology, Genetic Resources and Crop Evolution, Acta Societatis Botanicorum Poloniae

AWARDS AND SCHOLARSHIPS:

(2018) Josef Hlavka annual award for Czech students with the best outcomes and creative thinking

(2018) Scholarship for mobility to Indonesia within Erasmus Mundus ALFABET

(2017) Julia F. Morton Award for the best poster at the meeting of the Society for Economic Botany

(2016) Second place in the Asia-Pacific Rainforest Photo Competition. CIFOR: http://www.cifor.org/asiapacific-rainforest-summit/photo-competition/entries/?photo=140