CZECH UNIVERSITY OF LIFE SCIENCES PRAGUE

Faculty of Tropical AgriSciences

The Economic Botany of Small-Scale Cocoa Farms in Sulawesi, Indonesia

MASTER'S THESIS

Prague 2018

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Declaration

I, Kristýna Vydrová, hereby declare that I have done this thesis entitled *The Economic Botany of Small-Scale Cocoa Farms in Sulawesi, Indonesia* 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 Citation rules of the FTA.

In Prague 25th April

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Acknowledgements

This research was financially supported and could not be realized without the support of Swisscontact and the Faculty of Tropical AgriSciences of the Czech University of Life Sciences Prague (CULS Prague).

I would like to sincerely thank to my supervisor doc. Ing. Zbyněk Polesný, Ph.D. from the Department of Crop Science and Agroforestry of the Faculty of Tropical AgriSciences of the Czech University of Life Sciences Prague, for his overall help, comments and suggestions and valuable information while leading my thesis.

Furthermore, I would like to thank to Ing. Barbora Tůmová for her helpful advices and background provided during the time of my work in Indonesia, to Agnes Deno, my interpreter in Mamuju, for her assistance when working with local people and collecting the plant material, and to all Swisscontact staff for their help and support whenever I needed it.

I would also like to thank to Ing. Vladimír Verner, Ph.D. from the Department of Economics and Development of the Faculty of Tropical AgriSciences, CULS Prague, and to Ing. Lukáš Pawera from the Department of Crop Science and Agroforestry of the Faculty of tropical AgriSciences, CULS Prague, for their help with the preparation of my research proposal and with the data analysis. My great thanks go also to Meg Phillips, Program Coordinator, Swiscontact Indonesia, for her proofreading.

Most importantly I wish to thank to all participating respondents for sharing information about the farm economy and their knowledge and wisdom on traditional use of plants with intention to help to realize this work.

Special thanks go to Megan King, Deputy Country Director, Swisscontact Indonesia, for her support, care and patience during my convalescence period after an injury, without which I would not be able to return to the field and finish my research.

Abstract

In Sulawesi, the largest cocoa producing area in Indonesia, subsistent smallholder cocoa farmers generally cultivate their cocoa in complex agroforestry systems. These systems, layered with a diverse array of plant species, are believed to provide both environmental and economic benefits. Despite the socio-economic and ecological importance of cocoa agroforests in Sulawesi, very few studies have investigated them. This research aimed to explore the relationship between cocoa farms, livelihoods and biological and cultural diversity in West Sulawesi. In order to do so, the study examined useful plant diversity, ethnobotanical knowledge of particular species, farmers' species prioritisation, and the impact of this biodiversity on the household economy. A total number of 65 useful plant species belonging to 32 botanical families were encountered during field surveying. Species were proven to be multipurpose, 59% of the species reported could be used in two or more ways. The most common and most valued species were *Gliricidia sepium*, *Musa* spp., *Lansium domesticum*, *Durio zibethinus* and *Cocos nucifera*. Agrobiodiversity represented by the Shannon-Weiner index ranged from 0.14 to 2.46, while species richness calculated with Margalef's index varied between 0.29 and 2.56. The results did not verify the hypothesis that farmers participating in the GP-SCPP cultivate higher levels of agrobiodiversity on their farms. The gross margin per ha ranged from -108 USD to 4,810 USD. The results showed a positive moderately strong correlation between the farm gross margin per ha and agrobiodiversity. There was also a negative moderately strong correlation found between amounts of used pesticides and agrobiodiversity. Even though agrobiodiversity was found to have positive impact on farm economic performance, further research focussed on relationship between the levels of agrobiodiversity and farm profitability needs to be done.

Keywords: agrobiodiversity, agroforestry, cocoa, gross margin, Shannon-Weiner index, traditional knowledge

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List of the abbreviations used in the thesis

BI	Bahasa Indonesia
cm	centimetre
E	English
GAP	Good Agricultural Practices
GP-SCPP	Green Prosperity-Sustainable Cocoa Production Program
H	Shannon-Weiner index
ha	hectare
IV	Importance Value
K	Kalukku
kg	kilogram
km^2	kilometre square
LEV	Land Expectation Value
LL	Local Language
M	Magalef's index
m	metre
mm	millimetre
Mmj	Mamuju
R&D	Research and Development
S	Simboro

1. Introduction

Sustainable agriculture projects across the world often promote advanced biodiversity as one of the goals and outcomes of project strategy. The projects support advanced biodiversity in part by encouraging integrated crop management and plant diversification. Sustainable cultivation of cocoa has been described as an example of agricultural practice that supports the highest levels of biodiversity (Rice and Greenberg, 2000), which is even more important due to the fact that a majority of the global cocoa production is cultivated in areas that are deemed 'biodiversity hotspots' (Clough et al., 2009).

Cocoa farms, often a threat to forests and biodiversity in the tropics, can also provide environmental and livelihood benefits that outweigh those of other agricultural systems, particularly when cocoa is grown in an agroforestry system (John, 1999; Rice & Greenberg, 2000; Schroth & Harvey, 2007; Jagoret et al., 2014). However, small-scale farmers involved in programs focussed on the development of sustainable agricultural practices may be more inclined to cultivate higher agrobiodiversity anyway.

Cocoa farms that retain significant numbers of indigenous useful plants, including shade trees, planted fruit and other trees, shrubs and herbaceous plants, replicate structural and functional elements of the forest. The biodiversity contributes to soil conservation, thermal regulation, genetic and species conservation, carbon sequestration, watershed protection, while also providing habitat for wildlife and acting as reservoirs for seeds from the forest (Jose, 2009; Silva Moço et al., 2009; Jacobi et al., 2013). In addition to these environmental services, non-cocoa plant species on farms provide useful products consumed for subsistence and sold in local markets. Across the various seasons, non-cocoa species contribute to household livelihoods, and provide supplementary income when cocoa prices fall or disease strikes. Cocoa farms also often contain timber species that would otherwise be harvested from the native forests, which can be harvested for home construction, household use, and be sold to obtain further income to invest in their farm (Ofori-Bah & Asafu-Adjaye, 2011; Cerda et al., 2014; Jagoret et al., 2014).

However, the more recent practice of planting new cocoa lands with hybrid varieties requiring less shade means that new cocoa plantations are much less diverse than the mature plantations and do not have the same conservation value. Even though the incomes arising from unshaded cocoa can be higher, extra agrochemical costs would tend to reduce the profitability of these systems. In addition, the age of the maximum Land Expectation Value (LEV) tend to be much longer for the traditional growing systems than that between 18-29 years of unshaded hybrid varieties (Obiri et al., 2007). When biodiversity decreases, such as with the removal of shade trees, smallholder cocoa farmers are more vulnerable to global changes including demographic pressure, food insecurity, cocoa price volatility and climate change (Vaast & Somarriba, 2014). In spite of the purported potentials and abilities of cocoa agroforestry and the various recommendations from research and development agencies, very few attempts have been made to use cocoa agroforestry as a large-scale conservation instrument in tropical countries.

This research aims to explore the relationship between cocoa farms, livelihoods and biological and cultural diversity in West Sulawesi, Indonesia. It examines the retention and planting of useful species, some with high conservation value, on cocoa farms, and the role of these species in the farm economy. It is based on household surveys, field interviews, and ethnographic research among smallholder cocoa farmers; some of which are participating in the Green Prosperity Sustainable Cocoa Production Program (GP-SCPP), implemented by Swisscontact. It aims to verify the hypothesis that such sustainable agricultural practices encourage farmers to maintain cultivated diversity and that such higher biodiversity is beneficial, not only for the natural environment, but also for the households' income. The thesis also serves the additional purpose of examining the differences between farmers trained through GP-SCPP and farmers that did not participate in the program. Such information will assist Swisscontact in evaluation of the GP-SCPP.

2. Literature review

2.1. Study area

Indonesia is a presidential republic located in Southeast Asia consisting of more than 17,500 islands from which around 7,000 are uninhabited. The archipelago lies on the equator and stretches out through 3 time zones. Indonesia shares land borders with Malaysia, Papua New Guinea and East Timor (Figure 1). The capital city is Jakarta (Encyclopædia Brittanica, 2018a). Indonesia is, with its population of 260 million, the world's fourth largest country in terms of number of inhabitants (Indonesia Investments, 2018). The main religion is Islam, which makes Indonesia also the largest Muslim country in the world (Embassy of The Republic of Indonesia Prague, 2018). The ethnic composition of Indonesia is characterized by its wide variety. The country includes around 300 different ethnic groups and over 600 local languages. This diversity is expressed in the national motto "Bhinneka tunggal ika" ("Unity in diversity") (Encyclopædia Brittanica, 2018a; Indonesia Investments, 2018).

Indonesia is divided into 33 provinces (including two Special Territories of Nanggroe Aceh Darussalam and Yogyakarta) and the Special Capital Region of Jakarta. Provinces are further divided into regencies and districts (Embassy of The Republic of Indonesia Prague, 2018).

Figure 1. Map of Indonesia. *(Source: ANU, 2018)*

2.1.1. Sulawesi

The island of Sulawesi, formerly known as Celebes, is one of the Indonesian Greater Sunda Islands. The land area (including adjacent islands) is 188,522 km² (10 % of Indonesias' land cover). The number of inhabitants in 2010 was approximately 17,500,000 which represent about 7% of Indonesian population (The Economist, 2000; Encyclopædia Brittanica, 2018b). The population is formed by seven major ethnic groups with different culture and language. Even though the main religion is, similarly to the rest of Indonesia, Islam, many traditional practices are still retained among the Sulawesi people (Encyclopædia Brittanica, 2018b).

Geography of Sulawesi is almost completely mountainous. There area, with the exception of South Sulawesi province, no extensive lowlands. About 20% of the land area is above 1,000 m above the sea level (Whitten et al., 1987). The island of Sulawesi was created by the collision of the Asian and Australian Plates and island arcs from the Pacific. Due to this mixed origin, Sulawesi possesses a unique mixture of Indomalayan and Australasian flora and fauna. The number of higher plant species is in comparison to other Indonesian islands lower (around 5,000 species). However, this number is only an estimation since the Sulawesi flora has not been completely surveyed (Cannon, 2005). Even though Sulawesi does not have the richest terrestrial biodiversity among Indonesian islands, it has the highest proportion of faunal endemics (US AID, 2004). Based on elevation, three main ecoregions can be distinguished. These are: freshwater and peat swamp forest located around the cost, lowland forests in areas lower than 1,000 m above the sea level and montane forest in areas of higher elevation. Even though Sulawesi has not been affected by deforestation as much as Sumatra or Borneo, the forest loss is still high (Bell, 2015). Within only one decade (2000-2009) Sulawesi lost more than 15% of its forest cover. The most endangered and the most affected by deforestation are, due to their location in the areas most suitable for agriculture, the lowland forests, the area of which has been reduced by about one half (WWF, 2018). The causes of deforestation were mainly intensification of agricultural production and mining (Hence, 2009; Yuliani, 2015). Illegal logging represents another threat together with the lack of authority and implementation of existing regulations and environmental laws (WWF, 2018).

Sulawesi is administratively divided into 6 provinces, namely South Sulawesi (Sulawesi Selatan), West Sulawesi (Sulawesi Barat), Central Sulawesi (Sulawesi Tengah), South East Sulawesi (Sulawesi Tenggara), Gorontalo and North Sulawesi (Sulawesi Utara) (Nations Online, 2018). Even though there is some industry centred in the South Sulawesi around the island's capital city Makassar (Ujung Pandang), most of the population works in agriculture (The Economist, 2000). In 2004 agriculture made up 34 percent of the islands' economy (Hence, 2009). The farming systems can be divided into three main types: the lowland farming system dominated by rice cultivation, upland farming system, which is practiced in higher elevations on poorer soils unsuitable for rice, and a perennial farming system. The main cultivated crops are rice, maize, coconuts, cocoa, coffee, candlenuts and cassava (FAO, 2005; Rahmanulloh et al., 2012; Encyclopædia Brittanica, 2018b). In comparison to other large Indonesian island such as Sumatra and Borneo, the oil palm (*Eleis guinensis*) has not been cultivated on a large scale yet (Brad et al., 2015; Hamdani & Mustofa, 2015; Thoumi, 2017).

West Sulawesi

West Sulawesi (Sulawesi Barat) is one of the 6 Indonesian provinces located in Sulawesi. The province was established on October 5, 2004 after its separation from South Sulawesi Province. The total area is about 16,796 km². The population (2010) was 1,158,336 people. Despite the fact that the population is small, it is very diverse. The main ethnic groups are Mandar (49.15%), Toraja (13.95%), Bugis (10.79%), Java (5.38%) and Makassar (1.59%). Furthermore, 19.15% of people identify themselves as one of the various smaller ethnic groups (Pemerintah Provinsi Sulawesi Barat, 2017).

West Sulawesi Province is further divided into 5 regencies: Mamuju, Mamuju Utara, Mamasa, Majene and Polewali Mandar (Figure 2). The administrative and economic centre is the Mamuju town which lies on the trans-Sulawesi road going from Makassar city in the South Sulawesi to Palu in the Central Sulawesi. Another connection to Makassar is represented by a single airport located 27 km from the Mamuju town. Due to its favourable position on the Makassar Strait, the West Sulawesi harbours also serve as an important hub connecting Sulawesi and Borneo islands (Pemerintah Provinsi Sulawesi Barat, 2017).

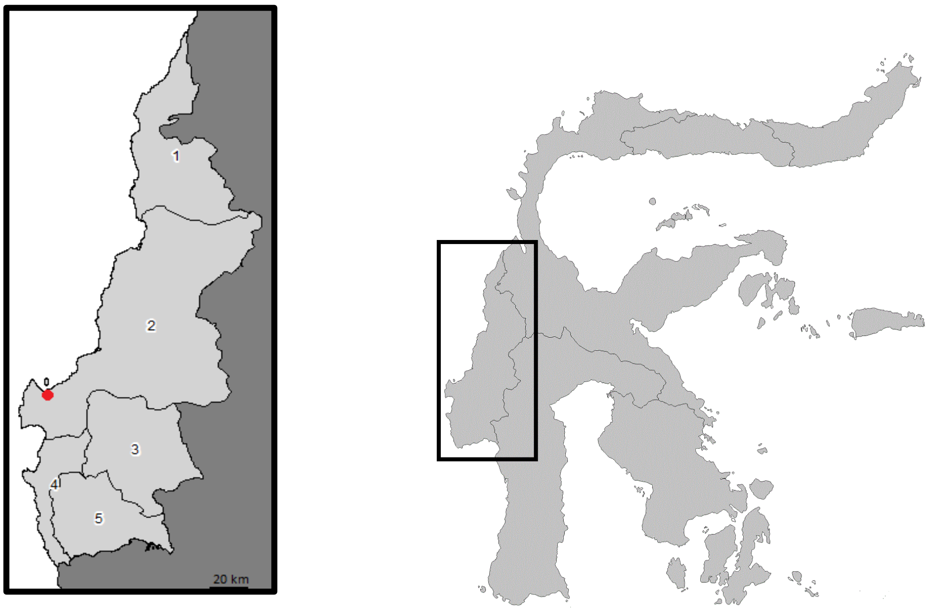

Figure 2. Regencies of West Sulawesi Province: 1. Mamuju Barat, 2. Mamuju, 3. Mamasa, 4. Majene, 5. Polewali Mandar. The red point represents the Mamuju town. *(Based on: d-maps.com, 2018)*

The economy of the West Sulwesi is based on agriculture, mining and fishery. The mining sector is focused on gemstone, gold, coal and petroleum. The agriculture in West Sulawesi is influenced by its topography. Rice is cultivated only in limited extension in lowlands around the coast or in valleys. The more mountainous areas are dominated mainly by cocoa. In addition to cocoa, robusta and arabica coffee, coconuts and clove are also cultivated (Pemerintah Provinsi Sulawesi Barat, 2017). The major soil types found in West Sulawesi are ultisols and inceptisols (FAO, 2005; Fahmuddin et al., 2015; Sarwani et al., 2015). Ultisols are reddish, tropical acidic soils typically with a shallow but hummus rich surface horizon and accumulated clay in the B horizon. Even though they are generally low in available minerals, especially calcium, they are naturally suitable for agroforestry, and can be made agriculturally productive with the application of lime and fertilizers (Wood & Lass, 1985; Plant and Soil Sciences, 2017a). Inceptisols are mineral soils of worldwide occurrence. Their origin is relatively new which leads to only weak appearance of horizons. They can be used for agriculture when properly managed. They are also believed to be suitable for cocoa if not sandy, extremely wet or shallow (Wood & Lass, 1985; Plant and Soil Sciences, 2017b).

Similarly to other parts of Indonesia, expansion of agricultural land in West Sulawesi is one of the main threats to local natural forests and the biodiversity they maintain. According to Global Forest Watch (2013), West Sulawesi lost approximately 133,000 hectares of tree cover between 2001 and 2012, which represents approximately 13% of provinces' forest cover (Figure 3).

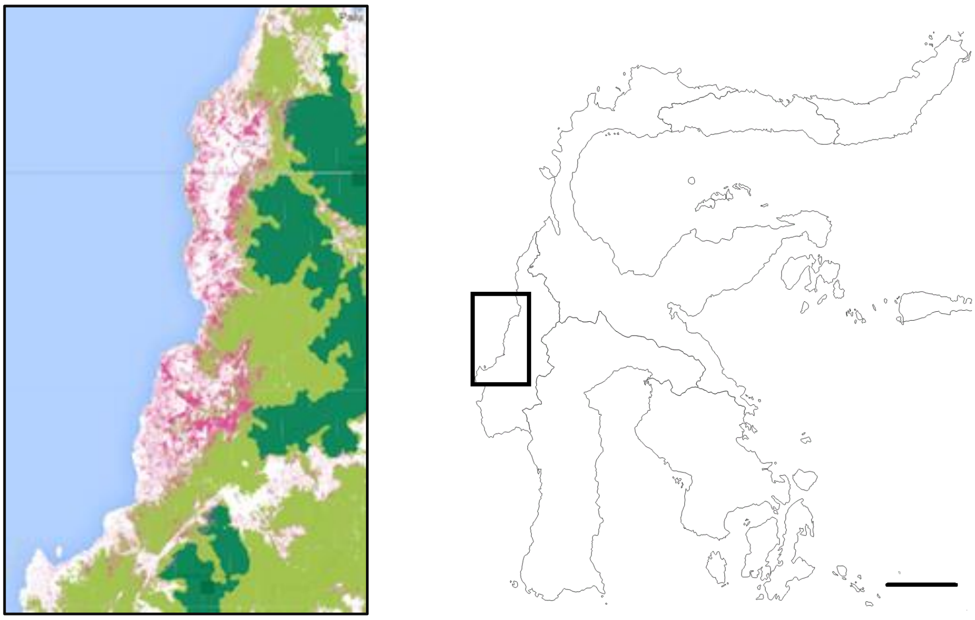

Figure 3. Deforestation in West Sulawesi. *(Based on: Global Forest Watch, 2013)*

2.2. Cocoa (*Theobroma cacao* L.)

Cocoa, source of one of the most famous and delicious products, chocolate, is a small tree 5-8 m tall, belonging to the genus *Theobroma,* a group of trees originating in the Amazon basin. There are over twenty species in the genus but the cocoa tree, *Theobroma cacao,* is the only one cultivated on a large scale. The natural habitat of the genus *Theobroma* is in the lower storey of the evergreen rain forest with high relative humidity, rainfall and uniform temperatures throughout the year (Wood & Lass, 1985; Valíček et al., 2002). From the commercial perspective, the species *T. cacao* is divided into three groups:

- Forastero (the most common group cultivated in Indonesia and worldwide)
- Criollo (the group most commonly associated with fine-flavour cocoa)

- Trinitario (x of Forastero and Criollo)

Cocoa tree belongs among cauliflorous trees (the flowers are formed on the trunk and branches of a certain minimum physiological age, which is usually two to three years in good growing conditions). Even though the cocoa tree blooms and bears fruit in two main seasons, a smaller amount of flowers and fruits grows whole year round. To obtain optimal yields, the canopy must be pruned. Pruning is done to obtain a desired canopy shape and to direct the energy that would be wasted on unnecessary branches to main branches bearing fruit. Cocoa generally loves a light overhead shade, which makes it a species with high agroforestry potential (Wood & Lass, 1985; Valíček et al., 2002).

The fruit, an egg-shaped yellow to red-brown berry, commonly called a pod, is usually 15-25 cm long with a knobby surface and ridges from top to bottom. It contains 30-40 seeds embedded in mucilaginous pulp. Pods are harvested manually after 5 to 6 months. Healthy ripe pods can be stored up to 10 days before opening. Seeds from ripened pods are cleaned of the pulp, fermented, dried (Figure 4) and then further processed (Wood and Lass. 1985; Simpson and Ogorzaly, 2001; KewScience, 2017).

Figure 4. Cocoa tree of forastero group with pods (left), cocoa beans extracted from pods (middle), drying of cocoa beans (right). *(Source: Kristyna Vydrova, 2017)*

2.3. Cocoa production in Indonesia

Indonesia is, with annual yields exceeding 330 thousand tonnes, the third largest cocoa producer in the world after Ghana and Ivory Coast and the most significant supplier of cocoa in East Asia (Panlibuton & Lusby, 2006; FAOSTAT, 2017a, ICCO, 2017).

Cocoa beans together with palm oil, rubber and coconut are the most important agricultural export products of Indonesia. In the global market, Indonesian cocoa is mainly traded as an unprocessed, unfermented, fat, bulk bean and volume base meaning that Indonesia loses out on added value revenues. The most important destination country for Indonesias' cocoa beans export is Malaysia followed by the USA and Singapore (Yasa, 2004; Indonesia Investments, 2015; FAOSTAT, 2017b). The Indonesian cocoa sector has experienced rapid growth in the past decades, driven by rapid expansion of smallholder farmers (Yasa 2004; Panlibuton & Lusby). Until now, smallholders contributed around 90% of national production, thus significantly outperforming big state or private plantations. In terms of land holding, on the average, smallholder farmers work on plots ranging from 0.5 to 1.5 hectares. Currently, cocoa yields in Indonesia range from 400 to 800 kg/ha, with the potential to increase yields up to 1,500 kg/ha (Yasa, 2004; GBG, 2014).

The main Indonesian cocoa producing region is the island of Sulawesi which accounts for more than 75% of Indonesia's total cocoa production. The remaining production takes place in North Sumatra, West Java, East Kalimantan and Papua (Figure 5). Some small production areas are also in Bali, Flores, and other islands (Yasa, 2004; Reuters, 2012; Indonesia Investments, 2015).

Figure 5. Cocoa production areas in Indonesia. *(Source: Swisscontact, 2018)*

2.4. Swisscontact and GP-SCPP

Swisscontact is the business-oriented independent foundation for international development cooperation. It was established in 1959 with the aim to promote economic, social and environmental sustainable development. Nowadays, Swisscontact works in 36 countries. Swisscontact has been working in Indonesia since 1972 (Swisscontact, 2018).

The Green Prosperity – Sustainable Cocoa Production Programme (GP-SCPP) is a partnership between the Millennium Challenge Account – Indonesia (MCA-Indonesia) and the Swisscontact Consortium. The main aim of this partnership is to reduce poverty and greenhouse gas emissions in the Indonesian cocoa sector. GP-SCPP is implemented in 14 districts in the provinces of South Sulawesi, Southeast Sulawesi, West Sulawesi, and East Nusa Tenggara. Its goal is to strengthen skills and knowledge of cocoa farmers in environmentally friendly cocoa farming, improved nutrition practices, and application of prudent financial practices, benefitting also women and vulnerable groups (Swisscontact, 2015).

In Mamuju regency, Swisscontact works with 7,345 farmers organized into 266 farmer groups. Approximately 14% are female farmers. The average age of farmers is 41.4 years and their family on average includes 4 people. Cocoa farmers in Mamuju are similar to the rest of Indonesia smallholders. Only about 7.8% of farms are bigger than 2 ha. The average cocoa farm size is 0.94 ha and the average annual yield in this area is 608 kg/ha. According to the previous studies conducted by Swisscontact, 78.4% of farmers in Mamuju use chemical fertilizers. The use of organic fertilizers is quite low, only around 3.2% of farmers apply some kind of organic fertilizer such as compost, or goat and chicken manure. Similarly to chemical fertilizers, other agrochemical use is also very common, 92.7% of farmers were reported to use chemicals to fight pests and diseases (PT. Koltiva, 2017).

To help increase cocoa yields of old low-productive farms, farmers are trained in grafting. Swisscontact also helps to establish cocoa nurseries producing high quality seedlings top grafted with superior cultivars providing higher yields, pest and disease tolerance or resistance against adverse environmental conditions such as drought

(Figure 6). The most common cultivars used on Sulawesi are cultivars of forastero group Sulawesi1 and Sulawesi2. The vast majority of beans are not fermented. The beans are usually sold just sundried or, in some cases, even wet (PT. Koltiva, 2017).

Figure 6. Cocoa nursery, grafting of cocoa (left), grafted seedlings (middle), detail of a top grafted seedling (right). *(Source: Kristyna Vydrova, 2017)*

Cocoa in Mamuju is usually grown in agroforestry systems. Based on data from the baseline interviews done prior to Good Agricultural Practices (GAP) farmer field schools, it is estimated that farmers maintain on average 265 shade trees per hectare, from which majority are fast-growing shade trees from the Fabaceae family (76%) and fruit trees (15%). However, this data is only based on farmers' guess, and there is no information on farmers motives for cultivation such species and their impact on farm economic performance. A study examining this topic is therefore needed.

3. Objectives

The main objectives of this study were to examine the retention and planting of non-cocoa plant species on cocoa farms participating and not participating in the Swisscontact Green Prosperity Sustainable Cocoa Production Program (GP-SCPP) and to examine the impact of these species on farm practices and farm economic performance. To fulfil the main objectives of the study, several intermediate objectives were established:

1. To perform an ethnobotanical inventory of agrobiodiversity on cocoa farms.
2. To assess the species richness using Margalef's index and to estimate the level of agrobiodiversity using Shannon-Weiner index.
3. To determine farmers' preferences for plant species on their cocoa farms and their importance value.
4. To investigate farming practices and farm economy.
5. To evaluate the relationship between the level of agrobiodiversity and farm gross margin/ha.

Hypotheses:

1. Increased levels of biodiversity have positive impact on farm economic performance.
2. Farmers participating in GP-SCPP retain higher levels of biodiversity on their farms.

4. Methods

4.1. Study site

The study was performed in the West Sulawesi Province in the Mamuju Regency. Climate in Mamuju is classified by the Köppen-Geiger-Pohl system as wet equatorial. It is characterised by consistently high temperatures, high precipitation and humidity, with very little annual temperature variation. The average annual temperature is 26.9 °C. The variation in temperatures throughout the year is only 1.6 °C. The average annual rainfall is 2,533 mm. Even though the amount of rainfall is high throughout the year, two main rainy seasons, with peaks in May and November, can be distinguished (Encyclopædia Britannica, 2017; CLIMATE-DATA.ORG, 2018). The mean annual relative humidity reaches 80% (Time and Date AS, 2017). A detailed distribution of temperatures and rainfall throughout the year is shown in Figure 7.

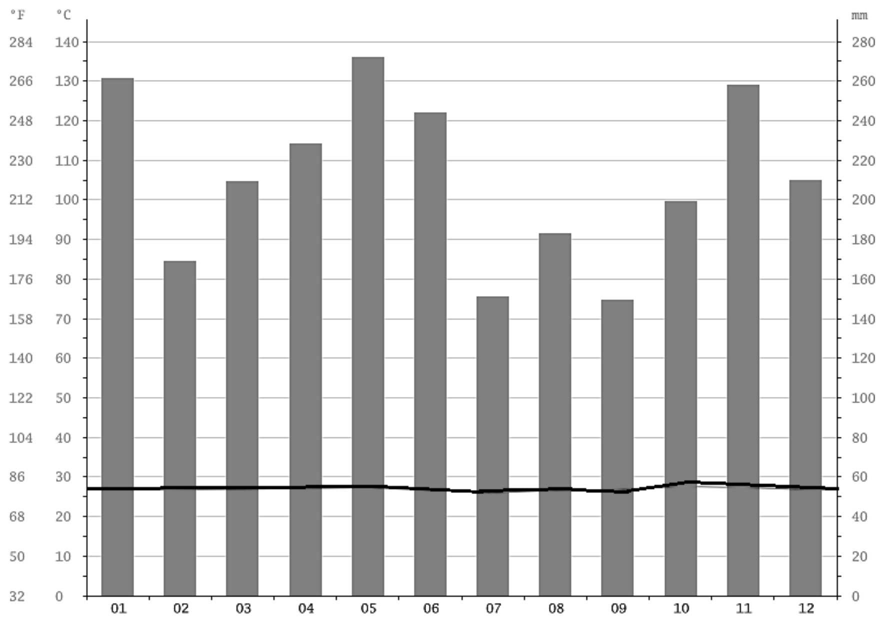

Figure 7. Climate diagram of Mamuju, Sulawesi Barat, Indonesia. *(Source: CLIMATE-DATA.ORG, 2018)*

After the consultation with Swisscontact R&D team and the local staff in Mamuju, two districts were chosen: Simboro and Kalukku (Figure 8).

Figure 8. Location of Simboro and Kalukku districts in Mamuju regency. *(Based on: KotaKita, 2014)*

These districts were selected due to their different geographical conditions that were believed to influence the farm management practices and composition of the non-cocoa species cultivated. The district of Simboro is more mountainous, and compared to Kalukku, has worse infrastructure. Cocoa farms in Simboro are often located in remote areas with difficult or no accessibility to local markets, especially during the rainy season when the unpaved roads get impassable (Figure 9).

Figure 9. Hardly accessible farms in Simboro. *(Source: Kristyna Vydrova, 2017)*

On the other hand, most of the villages and farms in Kalukku were located around the main road along the coast, connecting Mamuju with the Central Sulawesi Province (Figure 10).

Figure 10. Farms located around Trans-Mamuju road. *(Source: Kristyna Vydrova, 2017)*

The specific village selection was determined based on additional CocoaTrace[1] data and discussion among the GP-SCPP field staff. The selected villages were: Simboro, Botteng, Botteng Utara and Saletto in the Somboro subdistrict, and Kalukku, Sondoang, Guliling and Pamulukkang in the Kalukku district.[2]

4.2. Data collection

Field visits were conducted in March, April and May, 2017. A total number of 52 farmers were interviewed, 22 in Somboro and another 30 in Kalukku (Table 1.). As this study aims to compare farmers participating and non-participating in GP-SCPP, two different sample groups were made. One sample group consisted of cocoa farmers participating in GP-SCPP and the second sample group consisted of cocoa farmers that were not participating in GP-SCPP. The overall proportion of farmers in these groups were 36:16, in other words, 69 % of interviewed farmers were GP-SCPP participants. The GP-SCPP participants were preselected based on CocoaTrace data. The final list of farmers changed according to the discussion and advice of the field staff and farmer group leaders, the availability of farmers and their willingness to participate in the study. As we had no prior information about the farmers out of the GP-SCPP, they were selected directly in the villages according to the advice of village leaders or farmer group leaders. Such farmers were then visited and asked if they were willing to participate in the study.

[1] CocoaTrace is a web and mobile application developed by PT Koltiva that focuses on cocoa traceability and sustainability program management.
[2] Note: Two village names, Simboro and Kalukku, share the same name as the district where the villages are located.

Table 1. Interviewed farmers details.

District	Village	Farmer group	In GP-SCPP	Out GP-SCPP	Female farmers	Total no. of farms
Simboro	Simboro	Harapan Jaya	3	1	0	
		Sikamasei	3	0	0	
			6	**1**	**0**	**7**
	Botteng utara	Lestari Alam	5	0	1	
			5	**0**	**0**	**5**
	Botteng	Sikariori	3	0	0	
		_	0	4	0	
			3	**4**	**0**	**7**
	Saletto	Tunas Baru	3	0	1	
			3	0	1	3
			12	**5**	**3**	**22**
Kalukku	Kalukku	Tunas Harapan	3	0	0	3
	Sondoang	Tallu Ratte	0	5	0	
		Bunga Coklat	1	1	0	
		Tekun	2	1	1	
			3	**7**	**1**	**10**
	Guliling	Tallu Sikambi	5	0	3	
			5	**0**	**3**	**5**
	Pamulukkang	Tajang Pammase	8	3	2	
		_	0	1	0	
			8	**4**	**2**	**12**
			19	**11**	**6**	**30**
Total			**36**	**16**	**9**	**52**

Prior to any research activity, each participant was familiarized with the objectives of this study and asked to give informed consent. Several data-gathering methods, such as semi-structured interviews, ranking exercises, field observations and cocoa farm inventories, were used.

As most of the farmers did not know the exact size of their farm, this data were obtained from CocoaTrace. Information about the true size of the farm obtained was then used for the economic data refinement.

Data for the economic analysis, such as information about yields, selling prices, labour costs (land preparation and maintenance, planting, disease and pest control, harvesting) and other costs (farm tools, agrochemicals, planting and grafting material) were obtained from targeted farmers via semi-structured questionnaires (Appendix 1) and interviews (Figure 11). To assess the revenues, farmers were asked how many bags (kg) of cocoa they sold during each harvest and for what price. Cocoa prices were later verified with farmer group leaders and local traders. To determine revenues from non-cocoa crops, farmers were asked if and what kind of non-cocoa products they sell, how often, in what amount and for what price. The prices were then verified on local markets in Simboro and Kalukku towns. To determine expenses for hired workers, the farmers were asked if somebody helps them on their farm. If the answer was yes, they were asked if they pay them salary, how many times per year they hire them, for how many days and how much they pay them per day. To assess the expenses spent for fertilizers, farmers were asked how often they apply fertilizers, what type of fertilizer they apply, in what amount (how many bags they use per application and how many kg one bag weighs), and how much one bag costs. Pesticide (herbicides, insecticides and herbicides) expenses were assessed based on a series of questions, including what type of agrochemical they use, how often they use it, in what dosages (how many tanks they usually use per application and how much of the chemical they use per one tank), where they buy it and for what price. Prices for both fertilizers and pesticides were then verified with local dealers. Expenses for planting and grafting material were calculated from number of planted/grafted trees and the cost of one seedling or scion. Finally, farmers were asked if they had any other expenses (new tools etc.).

Figure 11. Interviews with farmers. *(Source: Kristyna Vydrova, 2017)*

When the questionnaire regarding farm economy was finished, farmers were asked to lead us to the farm centre where a sample plot 25×25 m was established (Vebrova., 2014). In this plot, all trees exceeding one meter in height and all useful herbaceous plants were counted and their local name was recorded (Appendix 2). Samples and photos of less known or completely unknown species were collected for future identification. Since this study does not intend to present the full enthnobotanical study, but rather an accurate view of the managed agrobiodiversity and its benefits, only the useful plants were recorded. All the wild plants considered as weeds or products collected in the adjacent forests were excluded from the questionnaire. When all the useful species were recorded, the farmers were interviewed about their knowledge regarding each species. They were asked if they planted the species or just maintained it on their farm, how they use them, which part is used and how, if they process it, and if they sell it and for what price (Maundu, 1995; Mahabub Nawaz et al., 2009). Uses mentioned by farmers were classified into nine categories: edible plants for home consumption, selling, medicine, firewood, fodder, shade, soil improvement and erosion protection, construction material/timber and others (Jagoret et al., 2014).

In order to determine farmers' preferences for non-cocoa species, they were asked to evaluate these plants on the basis of their uses. Each farmer got a cross-classification table in which the rows showed the local name of the plant species inventoried in the cocoa agroforest, while the columns indicated potential uses. Farmers were then asked to give each plant 1-10 point according to its importance to them. Furthermore, they were asked to divide these points between each category. Point distribution was then discussed (Jezeer, 2006; Jagoret et al., 2014). An example of such ranking exercise is shown in Figure 12.

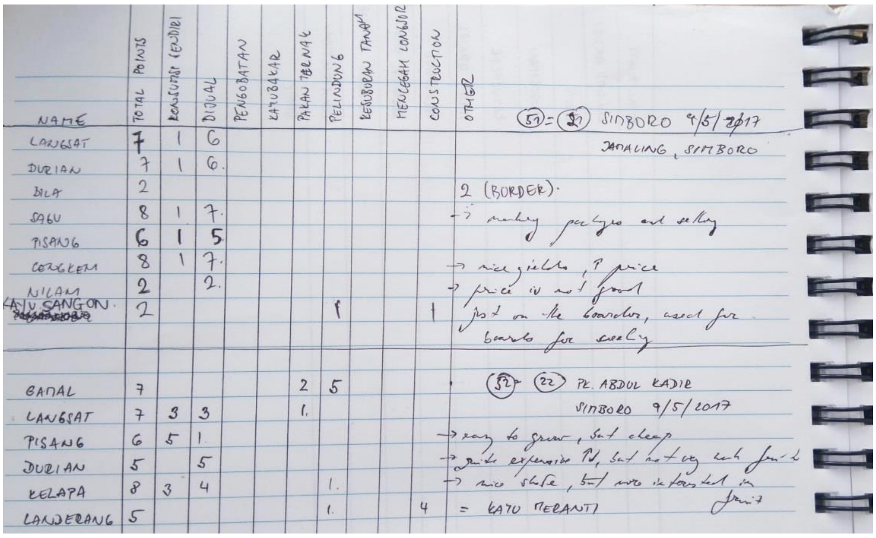

Figure 12. Ranking exercise. *(Source: Kristyna Vydrova, 2017)*

Finally, all the information was used to compile a list of all useful plants altogether with the farmers' knowledge and preferences.

4.3. Data analysis

The primary data collected in the field were converted from the field book and questionnaires into excel working sheets and analysed by descriptive statistics. For the analysis of the floristic composition of the agroforests, species richness and diversity were calculated using information from the sampling plots. The Species richness was defined using Margalef's index of species richness that uses the following formula:

$$M = (S - 1)/\ln N$$

Where *M* is Margalef´s index, *S* is the observed total number of species present in the sample and *N is the* total number of individuals in the sample. To estimate the degree of agrobiodiversity the Shannon-Weiner index was calculated. The formula used to calculate this index was:

$$H = \sum_{i=1}^{N} (p_i)(\ln p_i)$$

Where H is the Shannon-Weiner index, N is the total number of species i, and p_i is the proportion of species i in the community. Informants' ranking of plants was used to calculate the importance value of non-cocoa plant species. The importance value was calculated using the formula:

$$IV_s = \frac{n_{is}}{n}$$

Where IV_S is the importance value of the species, n_{is} is the number of points given by farmers, and n is the maximum number of points that species can be scored, i.e. number of farms multiplied by 10. To determine the most profitable management systems the gross margin per ha was calculated:

$$Gross\ margin/ha = Revenues/ha - Variable\ costs/ha$$

Where revenues per hectare were calculated as a sum of yields of cocoa in kg per ha multiplied by the selling price per kg, and the amount of non-cocoa products multiplied by their selling price per unit (kg, litre, packet, cup, piece) divided by farm size (ha). Variable costs per hectare were calculated as a sum of expenses spent for hired workers, fertilizers, insecticides, herbicides, pesticides, seedlings, scions and tools divided by farm size (ha).

To determine the impact of increased biodiversity on farm economy, the correlation analyses of degree of agrobiodiversity represented by Shannon-Weiner index and gross margin was used (Grittinger 1982; Gordon et al., 2007).

5. Results

5.1. Ethnobotanical data on non-cocoa species

5.1.1. Species composition and frequency of occurrence

A total number of 64 plant species belonging to 32 families was documented. There was no significant difference found between species planted or maintained by GP-SCPP farmers and non-GP-SCPP farmers. The variation between non-cocoa plant species was more visible between the two districts. Only 32 species were identical in both districts. In other words, 15 species were found only in Simboro and 17 only in Kalukku. For each species, the information on botanical and vernacular names, life form, way of use, plant part used and district in which the species was found are provided (Table 2). The most represented families were Araceae (6 species), Fabaceae (6 species), Myrtaceae (4 species) and Poaceae (4 species). All the plant families are listed in the Table 2.

Table 2. Plant families according to number of plant species belonging to each family.

Plant family	No. of species	Plant family	No. of species
Arecaceae	6	Araceare	1
Fabaceae	6	Basellaceae	1
Myrtaceae	4	Bignoniaceae	1
Poaceae	4	Bromeliaceae	1
Euphorbiaceae	3	Cactaceae	1
Lamiaceae	3	Caricaceae	1
Moraceae	3	Convolvulaceae	1
Piperaceae	3	Lauraceae	1
Zingiberaceae	3	Melastomataceae	1
Anacardiaceae	2	Musaceae	1
Malvaceae	2	Oxalidaceae	1
Meliaceae	2	Polypodiopsida*	1
Rubiaceae	2	Rutaceae	1
Solanaceae	2	Sapindaceae	1
Verbenaceae	2	Talinaceae	1
Annonaceae	1	Urticaceae	1
Araceare	1	Not identified**	1

* In case of one plant species only class was identified
** One plant species was not identified

The predominant plant life form in both districts were trees (29 species), followed by 10 species of herbaceous plants including bananas. As vines require special management in the cocoa agroforest, all creeping and climbing plants were included in this category. The proportion of different plant life forms is shown in Figure 12.

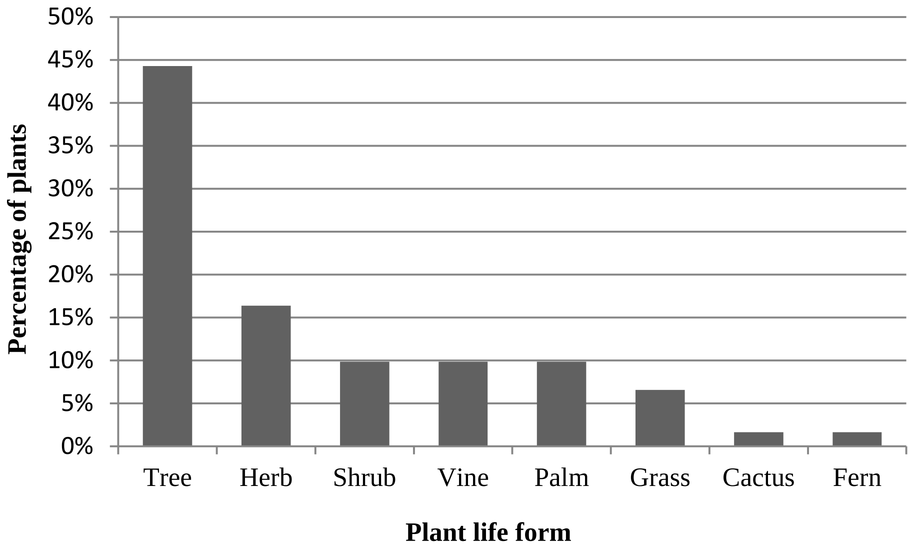

Figure 13. Life forms of non-cocoa species as a percentage of the total number of found non-cocoa species (n=65).

Table 3. Non-cocoa plant species.

Botanical name	Family	Local name	English name	Plant life form	Category of use*	Plant part used	District**
Albizia falcataria (L.) Fosberg	Fabaceae	Sengon laut	White albizia	Tree	Co	wood	S
Aleurites moluccanus (L.) Willd	Euphorbiaceae	Kemiri	Candlenut	Tree	HC, S, Sh	fruit	S, K
Alpinia galanga (L.) Willd	Zingiberaceae	Laos/Galanga	Galangal	Herb	HC, M	rhizome	S, K
Ananas comosus (L.) Merr	Bromeliaceae	Nanas	Pineapple	Herb	HC, S	fruit	K
Annona muricata L.	Annonaceae	Sirsak	Soursop	Tree	HC, S, M	fruit, leaf	S
Arachis hypogaea L.	Fabaceae	Kacang	Peanut	Herb	HC, SI	fruit	K
Areca catechu L.	Arecaceae	Pinang	Areca palm	Palm	HC, O	fruit	S
Arenga pinnata (Wurmb.) Merr	Arecaceae	Aren	Sugar palm	Palm	HC, S, Sh	sap	S, K
Artocarpus altilis (Parkinson ex F.A.Zorn) Fosberg	Moraceae	Sukun	Bread fruit	Tree	HC	fruit	S
Artocarpus heterophyllus Lam.	Moraceae	Nangka	Jack fruit	Tree	HC, S	fruit	K
Averrhoa bilimbi L.	Oxalidaceae	Belimbing buluk	Bilimbi	Tree	HC	fruit	K
Bamboo sp.	Poaceae	Bambu	Bamboo	Grass	HC, Fo, Co, O	stalk, leaf, sprout	S, K
Basella alba L.	Basellaceae	Lalede	Malabar spinach	Vine	HC	leaf	S
Borassus flabellifer L.	Arecaceae	Lontar	Palmyra	Palm	HC, Co	sap, leaf	S
Capsicum sp.	Solanaceae	Cabe	Chilli	Shrub	HC, S	fruit	S, K
Carica papaya L.	Caricaceae	Papaya	Papaya	Tree	HC	fruit, flower	S, K
Ceiba pentandra (L.) Gaertn	Malvaceae	Kapuk	Kapok	Tree	Sh, Co	wood	K
Citrus hystrix DC.	Rutaceae	Jeruk nipis	Lime	Tree	HC	fruit, leaf	S, K
Cocos nucifera L.	Arecaceae	Kelapa	Coconut	Palm	HC, S, Sh, Co	fruit, wood, leaf	S, K

Botanical name	Family	Local name	English name	Plant life form	Category of use*	Plant part used	District**
Coffea canephora (Pierre ex A.Froehner)	Rubiaceae	Kopi	Coffee	Shrub	HC, S	fruit	S
Colocasia sp.	Araceare	Talas	Taro	Herb	HC, Fo	tuber	K
Crescentia cujete L.	Bignoniaceae	Bila	Calabash tree	Tree	O	leave, fruit	S, K
Curcuma longa L.	Zingiberaceae	Kunyit	Turmeric	Herb	HC, M	rhizome	S, K
Cymbopogon citratus (DC.) Stapf	Poaceae	Sereh	Lemon grass	Grass	HC, M, O	stalk, leaf	S, K
Durio zibethinus L.	Malvaceae	Durian	Durian	Tree	HC, S, Sh	fruit	S, K
Elaeis guineensis Jacq.	Arecaceae	Kelapa sawit	Oil palm	Palm	HC	fruit	S
Etlingera sp.	Zingiberaceae	Honje, tikala	Torch ginger	Herb	HC, M	flower bud	S, K
Ficus sp.	Moraceae	Boda-Boda		Tree	M	leaf, root	S, K
Gliricidia sepium (Jacq.) Walp.	Fabaceae	Gamal	Quickstick	Tree	Sh, S, Fo, SI, FW	wood, branch	S, K
Gmelina arborea Roxb.	Lamiaceae	Jati putih	White teak	Tree	Co, S, Sh	wood	S, K
Hylocereus sp.	Cactaceae	Buah naga	Dragon fruit	Cactus	HC, S	fruit	S
Ipomoea batatas (L.) Lam.	Convolvulaceae	Keladi	Sweet potatoes	Vine	HC, Fo	tuber, leaf	K
Lansium domesticum Corrêa	Meliaceae	Langsat	Langsat	Tree	HC, S, Sh	fruit	S, K
Lantana sp.	Verbenaceae	Marica-rica/ bollo-bollong	Lantana	Shrub	M	leaf, flower	S
Leucaena leucocephala (Lam.) de Wit	Fabaceae	Lamtoro	Leucaena	Tree	Sh, Fo, SI, FW	wood	S, K
Mangifera indica L.	Anacardiaceae	Mangga	Mango	Tree	HC, S, Sh	fruit	S, K
Manihot esculenta Crantz.	Euphorbiaceae	Ubi	Cassava	Shrub	HC, Fo	tuber	S, K
Melastoma sp.	Melastomataceae	Mande-mande	Melastoma	Shrub	M	leaf, young branch	S, K
Metroxylon sagu Rottb.	Arecaceae	Sagu	Sago palm	Palm	HC, S, Sh		S
Musa sp.	Musaceae	Pisang	Banana	Herb	HC, S, Sh, Fo	fruit, leaf,	S, K

Botanical name	Family	Local name	English name	Plant life form	Category of use*	Plant part used	District**
						pseudostem	
Neolamarckia cadamba (Roxb.) Bosser	Rubiaceae	Uru	Cadamba	Tree	Co, Sh	wood	S, K
Nephelium lappaceum L.	Sapindaceae	Rambutan	Rambutan	Tree	HC, Sh	fruit	S, K
Peperomia pellucida (L.) Kunth	Piperaceae	Lumbu-lumbu	Pepper elder	Vine	M	aerial part	S
Persea americana Mill	Lauraceae	Alpucat	Avocado	Tree	HC	fruit	K
Psophocarpus tetragonolobus (L.) DC.	Fabaceae	Karibang	Winged bean	Vine	HC	fruit	S
Piper betle L.	Piperaceae	Sirih	Betel	Vine	M	leave	S
Piper negrum L.	Piperaceae	Merica	Pepper	Vine	HC, S	fruit, leaf	S, K
Pogostemon cablin (Blanco) Benth	Lamiaceae	Nilam	Patchouli	Shrub	S	aerial part	S
Poikilospermum suaveolans (Blume) Merr	Urticaceae	Mentawan	Poikilospermum	Vine	M	woody stem, leaf	S
Psidium guajava L.	Myrtaceae	Jambu batu	Guava	Tree	HC	fruit	S, K
Saccharum officinarum L.	Poaceae	Tebu	Sugar cane	Grass	HC, Fo	stalk, leaf	K
Solanum melongena L.	Solanaceae	Terong	Egg plant	Herb	HC	fruit	S
Spondias dulcis Parkinson	Anacardiaceae	Kedondong	Ambarella fruit	Tree	HC, Sh, Co	fruit, wood	S
Swietenia mahagoni (L.) Jacq.	Meliaceae	Mahoni	Mahagony	Tree	Co	wood	K
Syzygium aromaticum (L.) Merr. & L.M.Perry	Myrtaceae	Cengkeh	Clove	Tree	S, FW	flower, leaf, wood	S, K
Syzygium aqueum (Burm.f.) Alston	Myrtaceae	Jambu putih	Water apple	Tree	HC	fruit	K
Syzygium samarangense (Blume) Merr. & L.M.Perry	Myrtaceae	Jambu merah	Rose apple	Tree	HC	fruit	K
Talinum fruticosum (L.) Juss.	Talinaceae	Ginseng jawa	Ceylon spinach	Herb	HC, M	leaf, young shoot, root	S, K

Botanical name	**Family**	**Local name**	**English name**	**Plant life form**	**Category of use***	**Plant part used**	**District****
Tectona grandis L.f.	Lamiaceae	Jati	Teak	Tree	Co, S, Sh	wood	S
Vigna unguiculata (L.) Walp.	Fabaceae	Kacang panjang	Long beans	Herb	HC	fruit	S
Vitex cofassus Reinw. ex Blume	Verbenaceae	Kayu bitti	Vitex	Tree	Co, Sh	wood	K
Zea mays L.	Poaceae	Jagung	Corn	Grass	HC, Fo	fruit, stalk, leaf	K
*X****		Kayu meranti		Tree	Co, Sh	wood	S
*Y*****	Polypodiopsida	Pakis	Fern	Fern	HC	leaf	S

* HC (edible plants for home consumption), S (products for sale), M (medicine), FW (fire wood), Fo (fodder), Sh (shading for cocoa), SI (soil improvement and erosion protection), Co (constructions), O (other uses).
** S (Simboro), K (Kalukku).
***Unidentified species of local timber tree.
****Unidentified species of fern.

Most of the species were intentionally planted by farmers, only 12 wild species of mainly medicinal plants and local timber trees were wild and maintained/tolerated on farms (Figure 13).

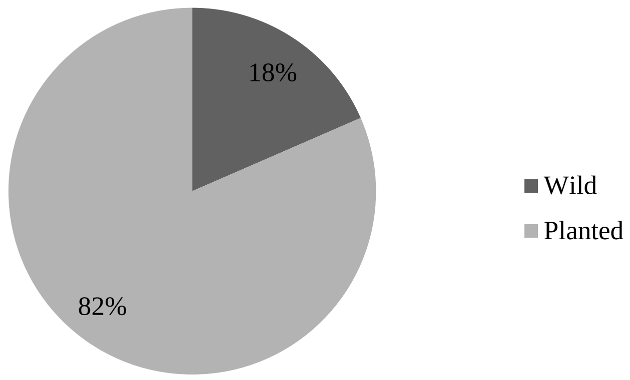

Figure 14. Percentage of wild and purposely planted plant species on cocoa farms.

The most common non-cocoa species found on more than 20% of farms were *Gliricidia sepium* (89%), *Musa* spp. (79 %), *Lansium domesticum* (70%), *Durio zibethinus* (65 %), *Aleurites moluccanus* (49%), *Cocos nucifera* (43%), *Capsicum* sp. (35%), *Psidium guajava* (23%), and *Carica papaya* (23%). The frequency of occurrence, i.e. the percentage of farms the particular species was found on, can be seen in the figure 15.

The frequency of occurrence of particular plant species was not the same in Simboro and Kalukku districts (Figure 16). Species such as *Durio zibethinus, Lansium domesticum, Aleurites moluccanus, Ananas comosus, Melastoma* sp., *Crescentia cujete* or *Neolamarckia cadamba* were much more common in Simboro than in Kalukku. On the other hand, the species *Arenga pinnata, Capsicum* sp., *Gmelina arborea, Leucaena leucocephala, Manihot esculenta, Musa* sp., *Psidium guajava* and *Syzigium aromaticum* were planted more often in Kalukku.

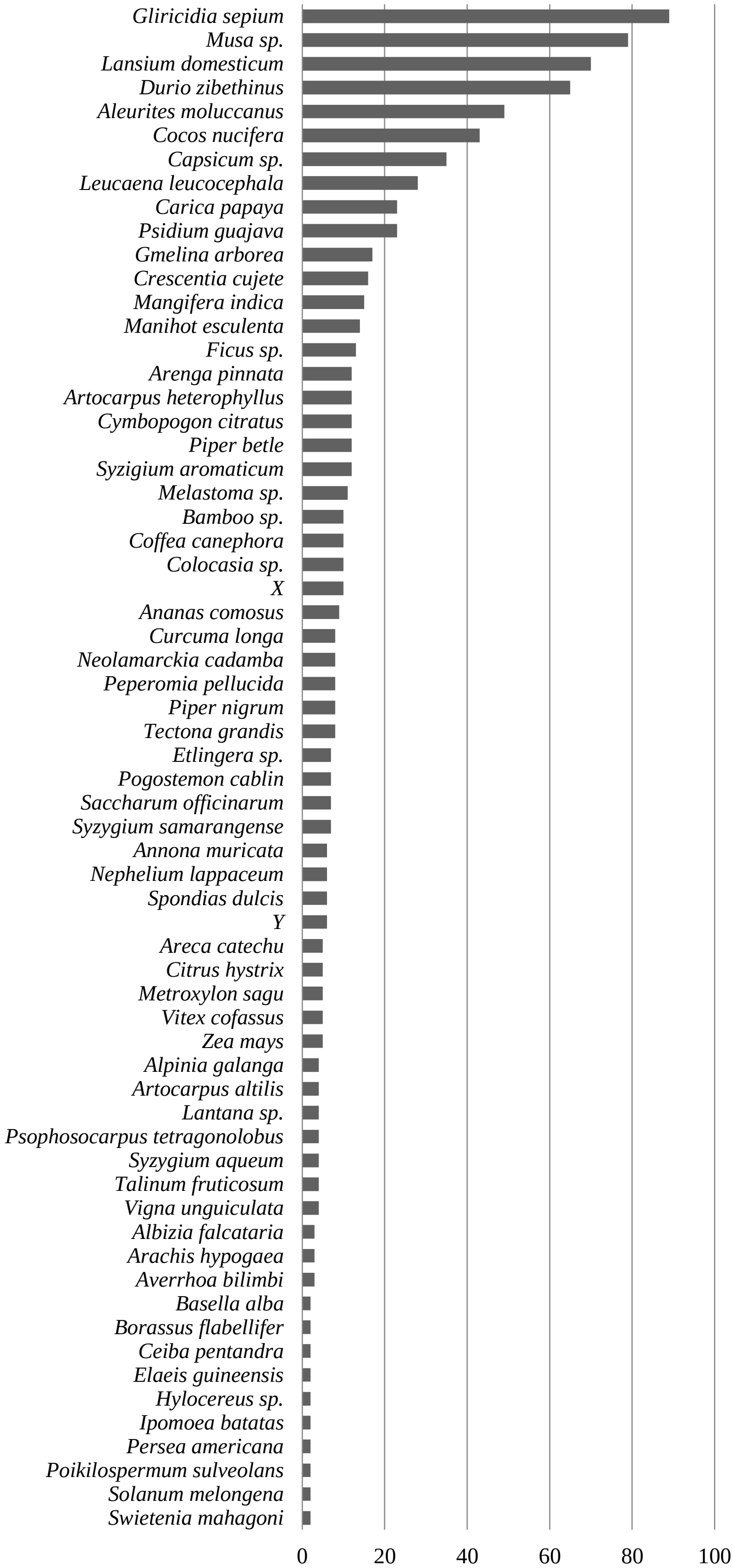

Figure 15. The frequency of occurrence of non-cocoa plant species found across all farms as a percentage of farms the species was found on.

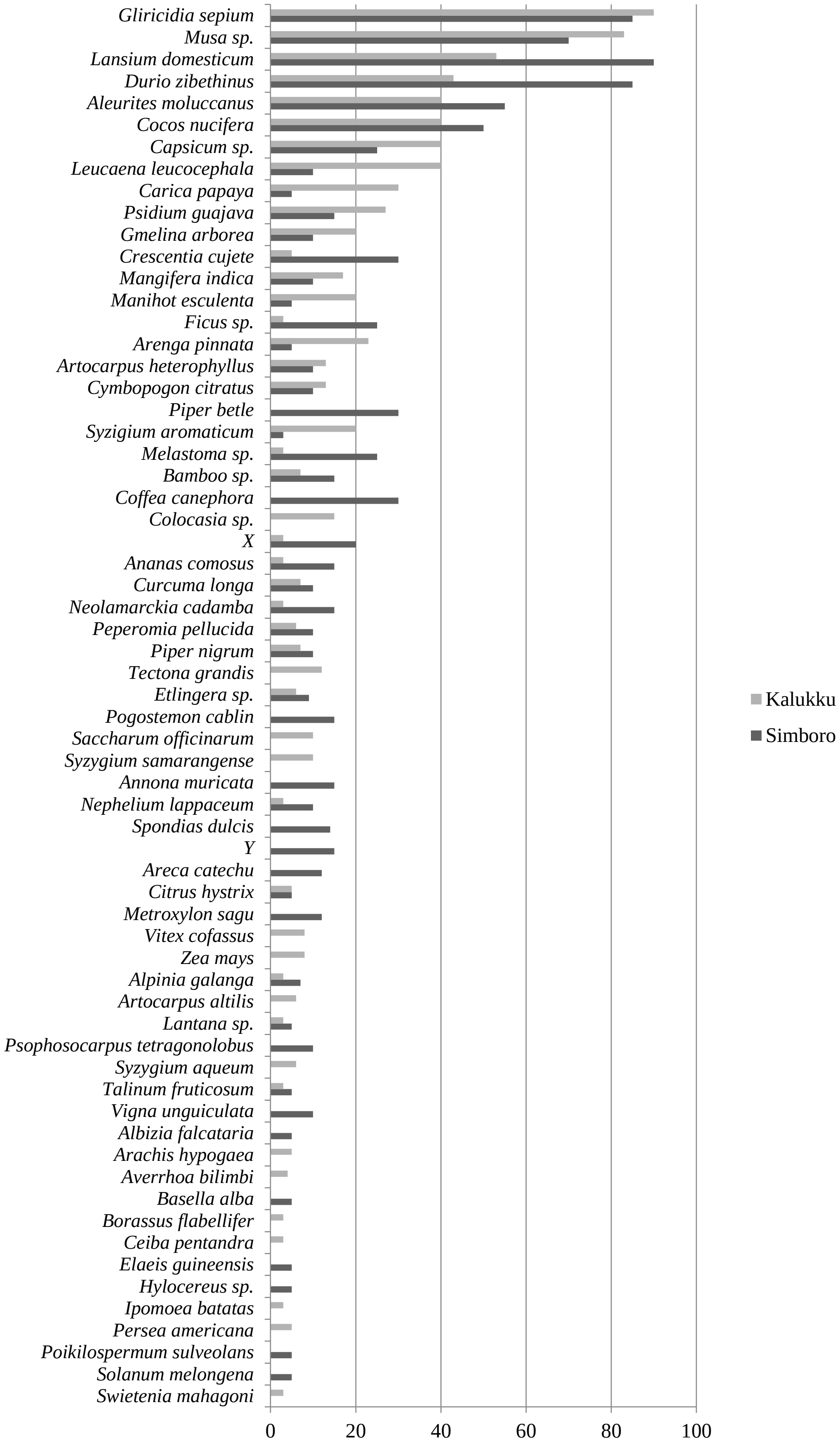

Figure 16. Differences in the frequency of occurrence of non-cocoa species in Simboro and Kalukku

Another pattern found for the species frequency of occurrence was religion. Even though the species composition was almost the same in all villages in a particular district, Gulilig, a mainly Christian village in Kalukku, was very different in terms of cultivated plants. Due to the different religion and habits derived from it (consumption of pork and alcohol), different dominant plant species were found. The dominant species cultivated in this village was *Arenga pinnata*, a sugar bearing palm with a sweep sap, which is collected and fermented to make a local alcoholic beverage called "tuak". Other dominant species were *Manihot esculenta* and *Ipomea batatas*. Tubers of these plants, and in the case of *Ipomoea batatas* also leaves and shoots, were used as a fodder for pigs (Figure 17).

Figure 17. Collection of sweet sap (left), *Ipomea batatas* (middle), preparation of fodder for pigs (right). *(Source: Kristyna Vydrova, 2017)*

5.1.2. Non-cocoa species use

Most of the non-cocoa plant species found in cocoa farms were proven to be multipurpose. Sixty-four percent of the reported plant species were used in more than one way. Furthermore, 25% of plant species were used in 3 or more ways (Figure 17). These multipurpose plant species were also, with the exception of *Annona muricata*, *Carica papaya* and *Mangifera indica*, the most frequently occurring. The non-cocoa plants were most often used for household food consumption (70%), selling at the local market (31%), or to provide shade for cocoa (28%). Twelve plant species (19%) were reported to be used as medicine. Surprisingly, only 4 farmers mentioned using non-cocoa species for soil improvement or for erosion protection. The percentage of non-cocoa species in different category of use shows following figure 18.

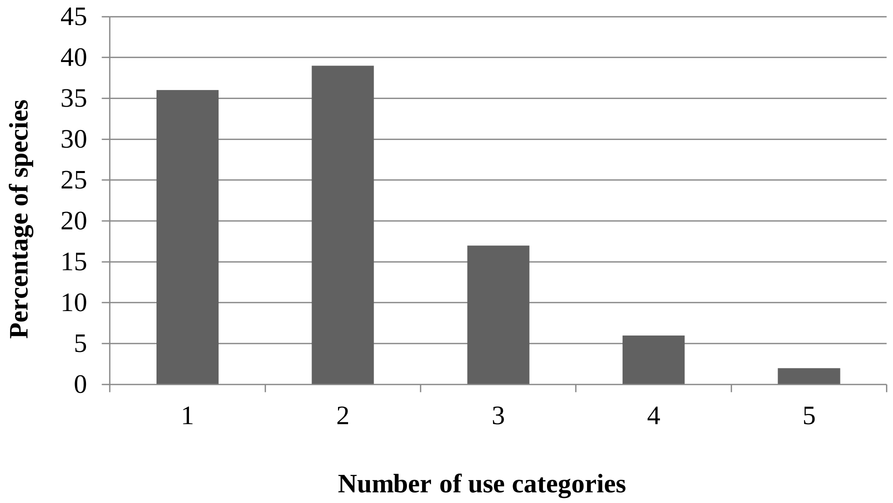

Figure 18. Percentage of species with different number of use categories reported.

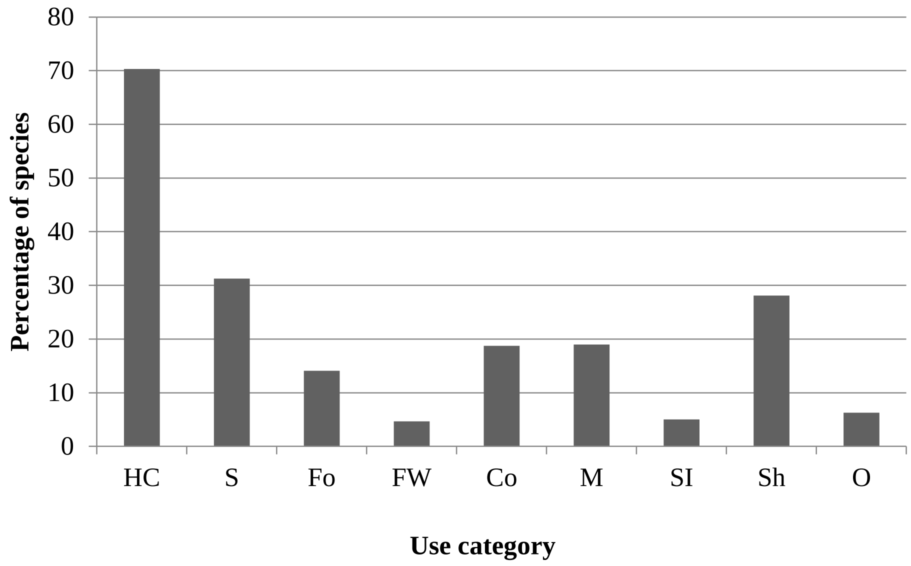

Figure 19. Percentage of non-cocoa species in different category of use. HC (Household Consumption), S (Selling), Fo (fodder for animals), FW (firewood), Co (constructions), M (medicine), SI (soil improvement and protection), Sh (shade for cocoa), O (other way of use).

In Figure 20, the proportion of different plant parts used is shown. The main plant part used by farmers was fruit (48 %), leaf (29 %), wood (18 %) and root, tuber or rhizome (18 %).

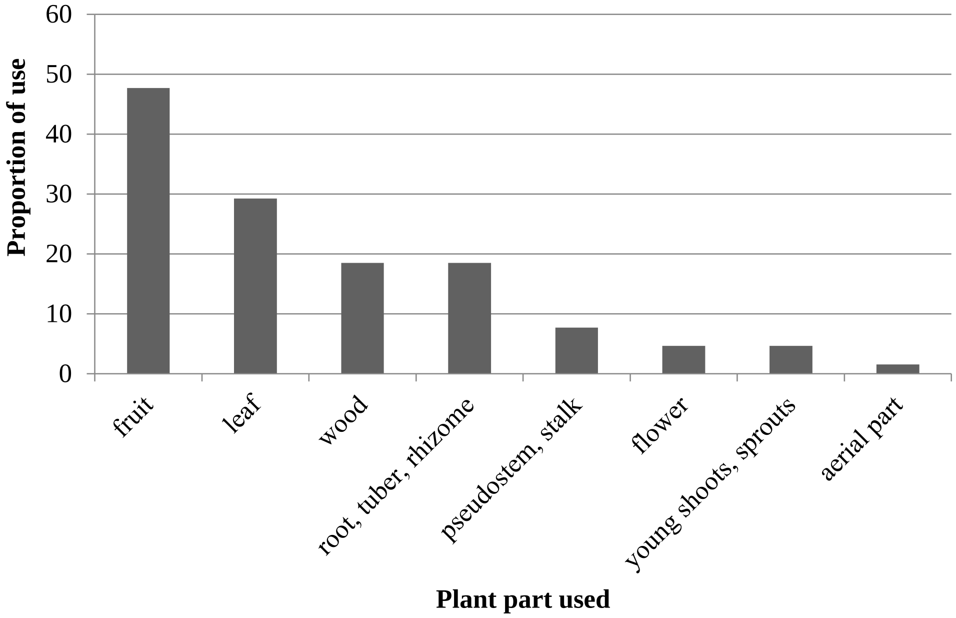

Figure 20. Proportion (%) of different plant parts used.

5.1.3. Farmers' preferences and Importance Value

To express their preferences for non-cocoa crops on their farm, farmers gave each of the species 1-10 points. There were no significant differences found between preferences between GP-SCPP and non-GP-SCPP farmers. However, there were differences between farmers' preferences for non-cocoa plant species among the two districts. Farmers in Simboro also gave their non-cocoa crops on average higher amounts of points. 64% of non-cocoa species in Simboro obtained more than 5 points out of 10. Plant species that obtained the highest average ranking, ie species that were most valued by farmers, in Simboro were: *Bamboo* spp., *Citrus hystrix*, *Ficus* sp., *Hylocereus* sp., *Metroxylon sagu*, *Musa* spp., *Nephelium lappaceum*, *Borassus flabellifer*, *Capsicum* spp., *Gliricidia sepium*, *Syzigium aromaticum*, *Averrhoa bilimbi*, *Cocos nucifera*, *Lansium domesticum*, *Phosocarpus tetragonolobus*, *Albizia falcataria*, *Arenga pinnata*, *Basella alba*, *Carica papaya*, *Coffea canephora*, *Cymbopogon citratus*, *Durio zibethinus*, *Ipomea batatas*, *Leucaena leucocephala*, *Manihot esculenta*, *Neolamarckia cadamba, Piper nigrum, Solanum melongena and Tectona grandis.* Also one unidentified species, refered to as Kayu Meranti in Indonesia, was given more than five points.

Only 43% non-cocoa species in Kalukku obtained such high rankings. These species were: *Albizia falcataria, Aleurites moluccanus, Ananas comosus, Arenga pinnata, Artocarpus heterophyllus, Averrhoa bilimbi, Bamboo* spp., *Cocos nucifera, Crescentia cujete, Ficus* sp., *Gliricidia sepium, Gmelina arborea, Leucaena leucocephala, Musa* spp., *Persea americana, Piper nigrum, Saccharum officinarum, Swetiana mahagoni, Syzigium aromaticum* and *Talinum fruticosum.*

As this ranking does not consider the number of farmers who cultivated a particular crop and thereof rated it, the importance of each non-cocoa species on the district and regency level was evaluated based on its Importance Value (IV). Species with the highest importance value ie species planted most often and most highly ranked, were: *Aleurites moluccanus, Capsicum* spp., *Cocos nucifera, Durio zibethinus, Gliricidia sepium, Lansium domesticum, Leucaena leucocephala, Melastoma* sp., *Musa* spp., and all three *Syzigium* spp. (*Syzigium aromaticum, Syzigium aqueum* and *Syzigium samarangense*).

All data regarding farmers' preference and IV are shown in the following table. The species of the highest Importance Value are highlited.

Table 5. Farmers' preferences for non-cocoa species and their Importance Value (IV).

Botanical name	**District**	**Mean ranking in K**	**Mean ranking in S**	**Mean ranking In Mmj**	**IV in K**	**IV in S**	**IV in Mmj**
Albizia falcataria	S, K	5.2	5.0	5.1	0.03	0.02	0.03
Aleurites moluccanus	**S, K**	**6.3**	**4.7**	**5.5**	**0.21**	**0.24**	**0.22**
Alpinia galanga	S, K	1.0	2.8	1.9	0.00	0,06	0,02
Ananas comosus	K	5.5			0.04		0,03
Annona muricata	S		1.5			0.03	0,01
Arachis hypogaea	K	3.5			0.04		0.02
Areca catechu .	S		3.8			0.05	0.02
Arenga pinnata	S, K	5.5	5.0	5.3	0.11	0.03	0.08
Artocarpus altilis	S		3.0			0.05	0.02
Artocarpus heterophyllus	K	5.3			0.07		0.04
Averrhoa bilimbi	K	5.1			0.20		0.21
Bamboo sp.	S, K	7.0	8.0	7.5	0.02	0.04	0.03
Basella alba	S		6.0			0.05	0.02
Borassus flabellifer	S		6.8			0.14	0.06
***Capsicum* sp.**	**S, K**	**4.6**	**6.8**	**5.7**	**0.20**	**0.14**	**0.17**
Carica papaya .	S, K	3.9	5.0	4.5	0.12	0.03	0.08
Ceiba pentandra	K	4.8			0.02		0.01
Citrus hystrix	S, K	4.2	8.0	5.8	0.01	0.03	0.02
Cocos nucifera	**S, K**	**5.1**	**6.4**	**5.7**	**0.20**	**0.23**	**0.21**
Coffea canephora	S		5.0			0.07	0.03
Colocasia sp.	K	3.0			0.04		0.02
Crescentia cujete	S, K	6.0	5.2	5.7	0.03	0.14	0.07
Curcuma longa	S, K	1.5	2.5	1.9	0,01	0.03	0.01
Cymbopogon citratus	S, K	4.5	6.0	5.1	0.06	0.03	0.05
Durio zibethinus	**S, K**	**3.8**	**5.8**	**4.8**	**0.13**	**0.46**	**0.26**
Elaeis guineensis	S		4.5			0.04	0.02
Etlingera sp.	S, K	4.5	4.5	4.5	0.06	0.06	0.06
Ficus sp.	S, K	7.0	8.0	7.5	0.02	0.04	0.03
Gliricidia sepium	**S, K**	**6.7**	**6.7**	**6.7**	**0.67**	**0.54**	**0.62**
Gmelina arborea	S, K	7.4	3.0	5.2	0.17	0.02	0.10
Hylocereus sp.	S		8.0			0.07	0.03
Ipomoea batatas	K	3.6			0.06		0.03
Lansium domesticum	**S, K**	**4.9**	**6.4**	**5.7**	**0.26**	**0.51**	**0.36**
Lantana sp.	S		3.0			0.07	0.03
Leucaena leucocephala	**S, K**	**5.8**	**5.5**	**5.7**	**0.25**	**0.06**	**0.17**
Mangifera indica	S, K	4.2	3.0	3.6	0.07	0.05	0.06
Manihot esculenta	S, K	3.6	6.0	4.8	0.06	0.03	0.05
***Melastoma* sp.**	**S, K**	**2.6**	**4.4**	**3.7**	**0.06**	**0.22**	**0.13**
Metroxylon sagu	S		7.6			0.07	0.03

Botanical name	District	Mean ranking in K	Mean ranking in S	Mean ranking In Mmj	IV in K	IV in S	IV in Mmj
***Musa* sp.**	**S, K**	**5.9**	**7.3**	**6.6**	**0.45**	**0.44**	**0.45**
Neolamarckia cadamba	S, K	3.0	5.3	4.2	0.01	0.08	0.04
Nephelium lappaceum	S, K	4.0	7.0	5.5	0.01	0.04	0.02
Peperomia pellucida	S		2.0			0.05	0.02
Persea americana	K	7.8			0.05		0.03
Psophocarpus tetragonolobus	S		6.2			0.06	0.03
Piper betle	S		3.4			0.09	0.04
Piper negrum	S, K	7.0	5.0	6.0	0.02	0.07	0.04
Pogostemon cablin	S		6.0			0.03	0.01
Poikilospermum suaveolans	S		2.0			0.01	0.00
Psidium guajava	S, K	2.0	3.5	2.8	0.06	0.04	0,05
Saccharum officinarum	K	5.9			0.05		0.03
Solanum melongena.	S		6.0			0.03	0.01
Spondias dulcis	S		4.5			0.04	0.02
Swietenia mahagoni	K	6.0	3.9	5.0	0.02	0.14	0.07
Syzygium aromaticum	**S, K**	**8.0**	**6.7**	**7.2**	**0.11**	**0.13**	**0.12**
Syzygium aqueum	**K**	**6.7**			**0.47**		**0.27**
Syzygium samarangense	**K**	**4.9**			**0.26**		**0.15**
Talinum fruticosum	S, K	5.3	4.0	4.7	0.07	0.02	0.05
Tectona grandis	S		5.5			0.12	0.05
Vigna unguiculata	S		2.4			0.03	0.01
Vitex cofassus	K	4.8			0.06		0.03
Zea mays	K	3.5			0.01		0.00
*X****	S		5.7			0.08	0.03
*Y*****	S		2.0			0.02	0.01

*S (Simboro), K (Kalukku), Mmj (Mamuju).
**Mean ranking in Mamuju was alculated only for plants found in both districts..
***Unidentified species of local timber tree.
****Unidentified species of fern.

5.2. Agrobiodiversity and species richness

The calculated values of agrobiodiversity (Shannon-Weiner index) varied between 0.14 on farms with almost no shade-trees and 2.46 on farms with various tree and herbaceous plant species. The species richness (Magalef's index) varied between 0.29 and 2.56. Both of these indicators were slightly higher on farms participating in the GP-SCPP program. The mean Shannon index was 1.53 on GP-SCPP participants' farms and 1.41

for non-participating farmers. The mean Magalef's index was 1.73 on GP-SCPP participants' farms and 1.65 for non-participating farmers. However no clear correlation (σ=0.0824) was found between Shannon-Weiner index and participation in GP-SCPP.

Some differences in agrobiodiversity levels were found also between the two districts. Simboro district was found to be richer than Kalukku. Farmers in Simboro planted or maintained on average 9.25 plant species, from which 6.25 were trees, which is almost two species more than in Kalukku (7.47). The mean Shannon and Magalef˝s index, respectively, was 1.55 and 1.80 in Simboro and 1.45 and 1.63 in Kalukku.

The results also suggest that female farmers are more inclined to have more diverse farms than male framers.

Table 4. Summary of agrobiodiversity indicators.

Parameters*	**Mamuju**	**Simboro**	**Kalukku**	**GP-SCPP**	**Non GP-SCPP**	**Females**	**Males**
Mean number of non-cocoa individuals	27.83	32.20	24.87	29.88	23.53	29.63	27.45
Mean number of non-cooca species	8.36	9.25	7.47	8.76	7.67	8.25	8.38
Mean number of non-cocoa tree species	5.88	6.25	5.63	5.91	6.00	4.75	6.10
Mean Shannon-Weiner index	1.49	1.55	1.45	1.53	1.41	1.63	1.46
Mean Magalef's index	1.70	1.80	1.63	1.73	1.65	1.80	1.68

*All parameters express values per sampling plot.

5.3. Selected species in detail

This chapter lists interesting and lesser known species. The species are presented the common names in Bahasa Indonesia (BI), local language (LL) or English (E), along with a botanical description and uses mentioned by farmers. Where there are many English common names available, only the most frequently cited are presented. The list of species is arranged in alphabetical order. Species that are not listed in this chapter are included in the list of all non-cocoa species identified on cocoa farms (Table 3).

***Crescentia cujete* L.**

Family: Bignoniaceae

Common names: bila (LL), calabash tree (E)

Description: *Crescentia cujete* is a small tree that can grow up to 10 m tall. It has an open crown, leaves are simple and obovate, usually varying in size, petiole is absent. Yellowish flowers with purple venation grow solitary or in pairs. The fruit is a spherical yellowish berry that reaches up to 30 cm in diameter, resembling the fruit of *Citrus grandis* or *Citrus paradisi* species (PROTA4U, 2018a).

Uses reported by farmers: Due to its shrubby growing habit, calabash trees were often planted as a fence to mark the farm borders. Fruit was used as medicine and organic pesticide. Juice from the fruit was used to treat diarrhoea and intestinal pain. To prepare the organic pesticide, the fruit was cut, mixed with water and boiled. The final solution was then applyed on cocoa trees. Thanks to its large size and spherical shape, the hard shell of the fruit were sometimes used as bowls.

***Lantana camara* L.**

Family: Verbenaceae

Common names: marica-rica (LL), common lantana (E)

Description: Common lantana is a shrubby plant that can grow up to 2 m tall. Twigs are rectangular and sometimes spiny. Leaves are egg-shaped with a pointed tip, the upper surface is hairy. Flowers are arranged in clusters, the colour varies from white, yellow to orange. Both flowers and crushed leaves are fragrant. Fruit is a berry, green when young, and black when mature (Herbsia, 2017).

Uses reported by farmers: Extract from boiled leaves is applied to skin to treat swellings and skin problems from mildly irritated skin to eczema. The extarct, when drank, was believed to clean the body thanks to its detoxifying properties.

***Melastoma* sp.**

Family: Melastomaceae

Common names: mande-mande (LL), melastoma (E)

Description: The genus *Melastoma* consists of a wide range of species, from which 22 can be found in Southeast Asia including Indonesia (Rajenderan, 2010; Joffry et al., 2012). Melastoma plants are usually shrubs (but sometimes also herbs or small trees). Leaves are simple with 1-4 veins on each side of the midvein. Flowers are bisexual, usually tetra or pentamerous pink, purple or blue. The fruit is a berry or a capsule (PROTA4U, 2018b)

Uses reported by farmers: Melastoma was used as a medicinal plant. The crushed leaves and young branches were applied directly on small wounds and cuts to stop the bleeding and to fasten the healing proces.

***Peperomia pellucida* (L.) Kunth**

Family: Piperaceae

Common names: lumbu-lumbu (LL), pepper elder (E)

Description: Peperomia pellucida is a fleshy annual herbaceous plant that grows up to 30 cm tall. The stem is branched, initially erect, becoming decumbent, rooting at nodes. The simple leaves are arranged spirally, blade is elliptical-ovate or almost triangular, usually 2–3.5 × 2–3.5 cm. Inflorescence is a spike up to 6.5 cm long. Flowers are small, bisexual. Fruit is a globose drupe 0.5–1 mm big, often sticky (PROTA4U, 2018c)

Uses reported by farmers: Pepper elder was used by women as a medicinal plant. Crushed leaves and watery stems were applied on abdomens to help against abdominal pain during menstruation or child birth. Juice from crushed leaves were believed to not only help against pain but also to make the whole child birth faster and easier. Boiled leaves were used to treat cold and cough.

***Poikilospermum suaveolens* (Blume) Merr.**

Family: Urticaceae

Common names: mentawan (BI), poikilospermum (E)

Description: Poikilospermum is a large woody liana. Leaves are alternate, broadly egg-shaped to oblong, usually 10-60 × 2-25 cm. Male and female flowers are separated, pink in colour. They are arranged in head-like clusters. Male clusters are around 3 cm wide, female clusters are bigger, on average 7 cm wide. Fruit is an oblong achene 4 mm big (National Park Board, 2013).

Uses reported by farmers: Crushed leaves and roots were used to treat fever. Long woody stems were used to tie things.

Figure 21. *Melastoma* sp. (left), *Crescentia cujete* (middle), *Poikilospermum suaveolens* (upper right), *Peperomia pellucida* (lower right). (*Source: Kristyna Vydrova)*

5.4. Farming practices and farm economy

In order to be able to evaluate and compare the economic performance of visited farms, all the data were expressed as data per 1 ha.

5.4.1. Costs

As farmers often did not invest much in their farms, the variable costs were generally low. The variable costs spent on maintaining 1 ha of cocoa farmland ranged from 29 USD/year (400,000 IDR/year) to 1,332 USD/year (18,500,000 IDR/year). The average variable costs spent per ha was 330 USD/year (4,576,692 IDR/year). These costs included wages for hired workers, costs for agri-inputs such as fertilizers, insecticides, herbicides and fungicides, costs for grafting material and seedlings, and various other costs (tools, protective equipment and mats for drying cocoa beans). The percentage share of different types of costs on farm variable costs is shown in the following figure:

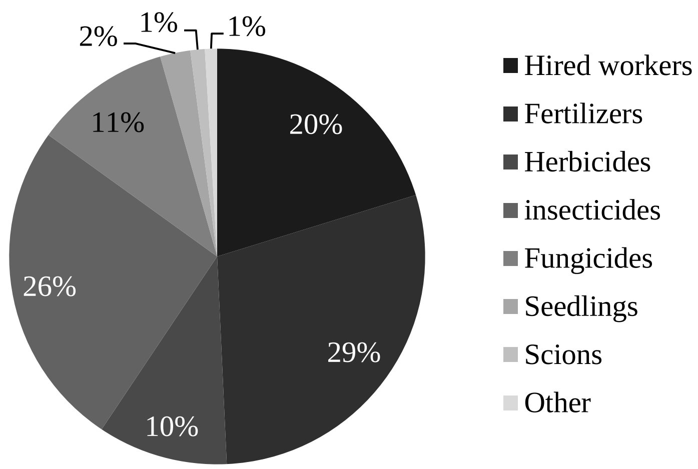

Figure 22. Percentage share of different type of costs on farm variable costs per ha.

As can be seen from figure 22, the major share on the farm variable costs represented chemicals used against pests and diseases (47%). Eighty-five per cent of farmers reported using herbicides, 92% used insecticides and 21% used fungicides. Unfortunately, chemicals were often used in higher amounts than necessary or in higher amounts than advised on the labels. A lot of farmers believed that use of chemicals in higher amounts than advised would improve the yield. Another problem was the type of pesticides being used. All herbicide brands used by farmers and the most common brands of insecticides contained active ingredients that appear on the list of banned ingredients[3] or watchlist[4] ingredients according to UTZ certified (UTZ, 2015). The list of all used pesticides together with percentage of farmers using them, the local price and the information on the active ingredients and its status is provided in the following table.

Table 6. Details on used herbicides, insecticides and fungicides.

Item	% of farmers	Minimal price*	Maximal price*	Median price*	Active compound	Status**
Herbicides	**85**					
Gramoxone	45	7.20	10.80	8.50	Paraquat	B
Noxone	8	4.32	5.76	4.68	Paraquat	B
Basmilang	2	4.68	4.68	4.68	Isopropil Amina Gliphosate	W
Rumat	8	3.96	3.96	3.96	IPA Gliphosate + 2,4 D	W
Rambo	6	3.96	8.64	7.20	Isopropil Amina Gliphosate	W
Supremo	12	6.48	9.36	7.92	Isopropil Amina Gliphosate	W
Polaris	4	4.90	5.04	4.97	Isopropil Amina Gliphosate	W
Insecticides	**92**					
Alika	36	3.96	8.64	7.20	Lambda Cyhalotrin & Thiametoxan	W
Penalty	19	5.76	9.36	9.00	Fipronil	W
Nurelle	4	8.64	8.64	8.64	Chlorpyrifos, Cypermethrin	W
Starban	7	6.12	6.12	6.12	Chlorpyrifos, Cypermethrin	W
Drusban	9	2.88	2.88	2.88	Chlorpyrifos	W
Bento	7	1.80	5.40	3.96	Cypermethrin	
Vigor	4	3.96	3.96	3.96	Cypermethrin	
Chlormite	6	3.60	4.75	3.96	Chlorpyrifos	W
Fungicides	**29**					
Nordox	24	4.18	9.00	7.56	Copper Oxide	
Heksa	2	-	-	-	Hexakonazol	
Rudal	3	-	-	-	Flutriafol	

*USD/item

**B (banned), W (watch list).

Even though the problems with pesticide use were recorded among farmers participating in GP-SCPP as well, GP-SCPP participants generally acted more

[3] Pesticides containing compounds with proved acute or chronic toxicity.
[4] The Pesticides Watchlist is composed of active ingredients that are not banned but that have a potentially severe and/or cumulative risk for human health and/or the environment.

responsibly and environmentally friendly. The correlation between participation in the GP-SCPP program and amount of money spent on pesticides was negative and of moderate intensity (σ= -0.3485). This means, farmers in the GP-SCPP program spent less money on pesticides than those not participating in GP-SCPP. Farmers in GP-SCPP spent on average 136 USD/year (1,889,027 IDR/year) on pesticides in comparison to 166 USD/year (2,299,066 IDR/year) spent by farmers that did not participate in the program. However, the brands of pesticides used by GP-SCPP farmers were the same as those used by farmers not participating in the GP-SCPP program.

The second biggest cost was chemical fertilizers. Chemical fertilizers were used by 98% of farmers. As can be seen in the table, only two types of chemical fertilizers were used. These were urea, NPK, or a combination of both. On average, farmers used 550 kg of fertilizers per ha over two or three applications cycles. The average cost spent on fertilizers was 95 USD/year (1,317,500 IDR/year). The correlation coefficient σ between participation in GP-SCPP and costs spent on fertilizers was -0.0069, which means there was no correlation found between the amount of chemical fertilizers used and participation in GP-SCPP.

Organic fertilizers were used by 52% of farmers. However, they were usually applied only in small amounts and not on a regular basis. The most common organic fertilizers were goat and chicken manure, and compost. As the organic fertilizers were usually produced by the farmers themselves, the costs spent on them were minimal (on average 6.36 USD/year). Even though the farmers participating in the program had been familiarized with the importance of organic fertilizers and their positive impact on soil properties, they did not apply the organic fertilizers more often than the farmers that did not participate in the program. .

Table 7. Details on used fertilizers.

Fertilizer	% of farmers	Minimal price*	Maximal price*	Median price*
Urea	41	6.84	10.80	7.20
NPK	35	8.50	15.20	12.72
Urea and NPK	22	-	-	-
Organic	52	0.00	1.80	0.00

*USD/1 bag (50 kg).

The third largest costs were paid for hired workers. The wage of one hired worker ranged from 3.6 USD/day (50,000 IDR) to 8.6 USD/day (120,000 IDR/day). The costs for hired workers per ha ranged from 0 USD/year, when farmers did not hire anybody to help them on their farm, to 480 USD/year (6,672,000 IDR/year). The average cost for hired workers was 79 USD/year (1,094,326 IDR/year). There was no correlation between participation in the program and higher use of hired workers. The main determinant was simply the number and age of family members. If the farmers had enough people to help them for free, they did not hire any workers.

The costs spent for seedlings, scions used for grafting, and tools were only marginal. They represented only about 4% of farm variable costs per ha. Only 17% of farmers planted new trees during the past year and their number was low, with the exception of one entirely replanted farm. Forty-five per cent of farmers grafted their trees with a new superior material. The most common cultivars used for scions were Sulawesi1 and Sulawesi2. The average number of newly grafted trees per ha was 52. Prices of seedlings, scions and tools are shown in table 8.

Table 8. Details on seedlings, scions and tools.

Item	Minimal price*	Maximum price*	Median price*
Tank	25.20	43.20	36.00
Mat for drying beans	7.20	10.80	10.51
Other equipment	0.72	18.00	7.20
Seedlings	0.50	0.58	0.50
Scions	0.04	0.50	0.36

*USD/item.

5.4.2. Revenues

As expected, the highest revenues were from selling cocoa beans. The average annual yield was 714 kg/ha. Even though the average annual yields were slightly higher in Kalukku (742 kg/ha) than in Simboro (697 kg/ha), there was no correlation found between the district and annual yields of cocoa per hectare (σ=0.0454). Even though the average yields did not vary much on the district level, the variability of annual yields among individual farms was quite high, especially in Simboro. The lowest recorded yield of a producing farm (one farm was replanted at the beginning of 2016, thus had no crop) was only 163 kg/ha. In comparison to that, the highest yield was approximately 2,400 kg/ha (Figure 23).

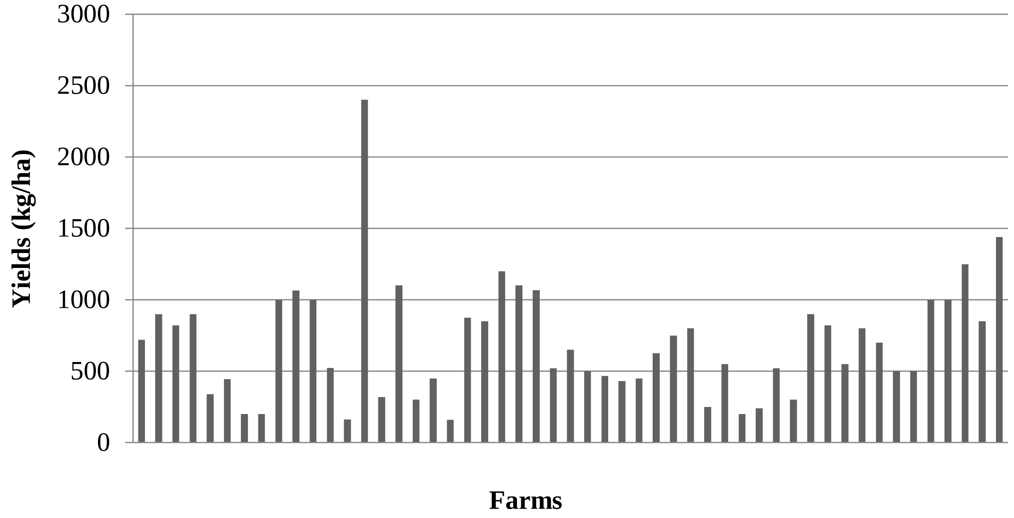

Figure 23. Variation of yields (kg/ha) among all visited farms (n=52).

Cocoa yields were found to be positively influenced by the amount of fertilizers used ($\sigma = 0.2264$). The correlation between yields per ha and the amount of fertilizers expressed as costs spent on fertilizers (USD/ha) is shown in the following figure:

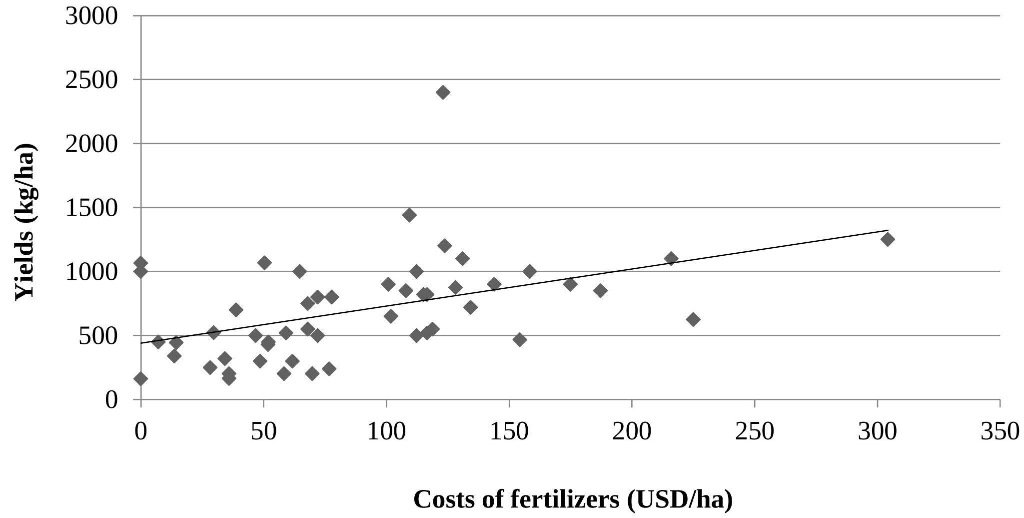

Figure 24. Correlation between cocoa yields (kg/ha) and costs spent on fertilizers among selected farmers (n=50).

No clear correlation (σ=0.0755) was found between cocoa yields and the money spent for pesticides (herbicides, insecticides and fungicides).

A positive correlation of low intensity (σ= 0.1060) was found between participation in GP-SCPP and cocoa yields. This means, that farmers participating in the program tended to have slightly higher yields. The average annual yields of farmers participating in GP-SCPP were 810 kg/ha which was about 120 kg more than those of farmers not participating in the GP-SCPP.

The revenues from cocoa (on producing farms) ranged between 144 USD (2,000,000 IDR) and 6,050 USD (84,000,000 IDR) per hectare per year. The average revenue was 1,888 USD (26,220,423 IDR). The differences in revenues were caused not only by the different productivity of cocoa farms but also by the cocoa prices. The cocoa prices varied between 0.86 USD/kg (12,000 IDR/kg) and 3.46 USD/kg (48,000 IDR/kg). The prices varied not only between the two districts but also among the villages and particularly farmer groups. Stronger and better organised farmer groups with a capable leader, who was able to organise farmers to sell their cocoa together as a whole group were able to obtain better prices than farmers selling their cocoa beans individually to traders at the "farm gate" price. An example of such a well-organised group was the Tallu Sikambi group in Guliling. The selling prices also depended on the type of the buyer. Small village traders generally bought the beans for a lower price than those working on a district or regency levels.

There were no big differences in prices of fermented and unfermented beans. The fact that the price for fermented beans was only about 0.04 USD/kg (500 IDR/kg) to 0.14 USD/kg (1,500 IDR/kg) higher than the price for unfermented ones, was the main reason why the farmers were not interested in fermenting their beans and improving the quality. Only 43% of farmers tried to ferment their beans, and only 12% of farmers did it for an adequate amount of time, which is 3 days in Mamuju (Figure 25). Additionally, even farmers trained in GP-SCPP often did not do the fermentation properly and in a safe way. A common method used for fermentation was fermenting the cocoa beans in sacks previously used to store fertilizers, which could lead to contamination of the beans by the chemical residues.

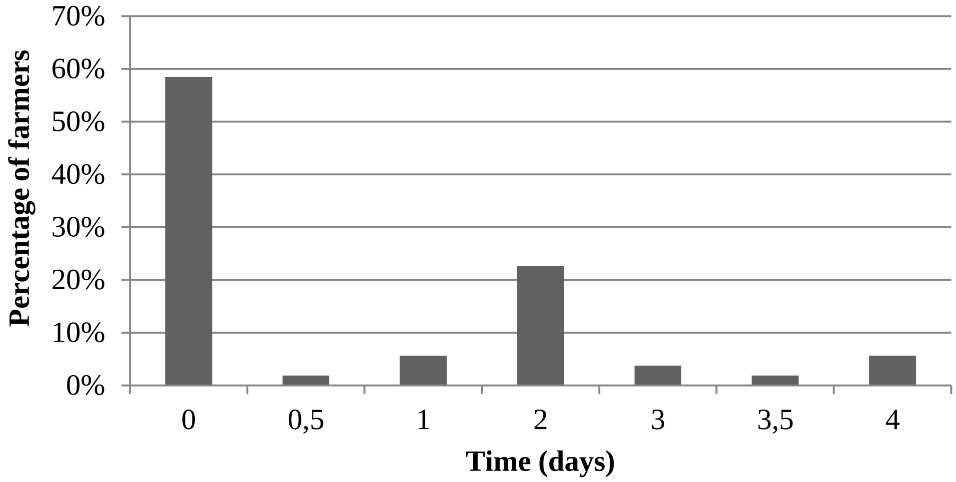

Figure 25. Percentage of farmers fermenting their beans and fermentation times in days (0-farmers do not ferment their beans).

Even though the main revenue from the farms were from cocoa the revenues from the non-cocoa crops were not negligible. The revenues from non-cocoa species per ha varied between 0 USD/year, if the farmer did not sell anything, to 648 USD/year (9,002,500 IDR/year) from farms selling various products. The average revenues from non-cocoa species was 126 USD (1,744,516 IDR/year). The revenues from non-cocoa species contributed from 0% up to 41.3% of the total farm revenues (Figure 26). On average, non-cocoa crops contributed to 7.3% of farm revenue.

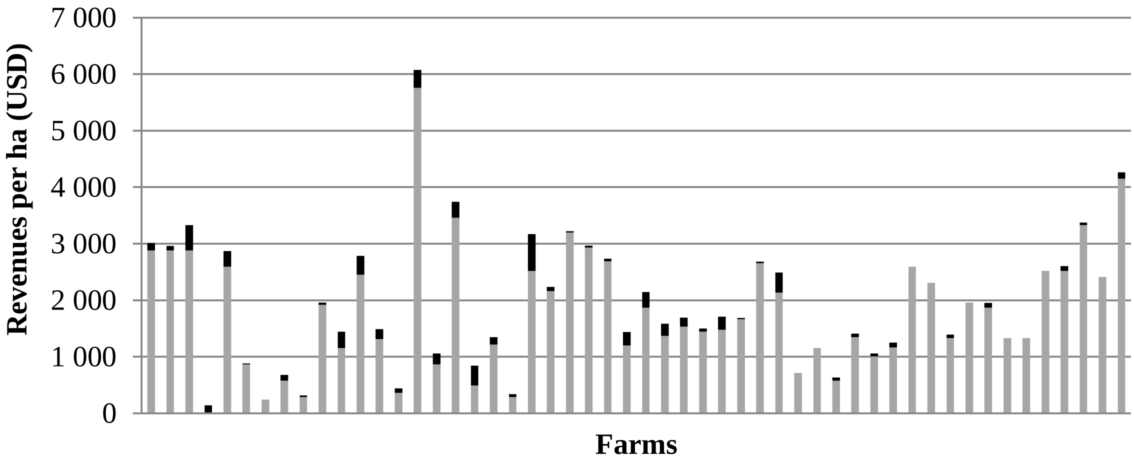

Figure 26. Share of non-cocoa crops (black) and cocoa (grey) on farm revenues per farm (n=52).

In total 28 products from 22 plant species were sold. Species of the highest economic importance were: *Aleurites moluccanus*, *Cocos nucifera*, *Lansium domesticum*, *Musa* spp., *Durio zibethinus*, *Syzigium aromaticum* and *Arenga pinnata*. The selling price depended on several factors. These were: the quality of the sold product, the bargaining ability of the seller and the person the product was sold to (the village members and friends got usually better price than people on markets in other villages or in Mamuju town). In case of fresh fruit sold per piece the price varied also according to the fruit size. All products used for selling together with their selling price per their selling unit are listed in the following table:

Table 9. Non-cocoa products sold and their selling prices (USD/unit).

Botanical name	Product	Minimal price*	Maximal price*	Median price*	Unit
Aleurites moluccanus	raw nuts	0.14	0.36	0.25	kg
	roasted and deshelled nuts	1.20	1.65	1.44	kg
Annona muricata	fruit	0.07	0.22	0.14	fruit
Arenga pinnata	palm sugar	0.07	0.43	0.29	piece
Arenga pinnata	palm wine (tuak)	0.30	0.52	0.36	l
	palm sugar	0.14	0.58	0.43	piece
Artocarpus heterophyllus	fruit	1.80	2.52	2.16	fruit
Capsicum sp.	fresh fruit	0.14	0.43	0.29	glass
	dried fruit	0.36	0.58	0.50	glass
	sambal	1.08	1.80	1.44	packet
Cocos nucifera	fruit	0.07	0.90	0.18	fruit
	copra	-	-	0.86	kg
	oil	1.56	1.92	1.73	l
Coffea canephora	coffee (roasted, grounded)	0.36	0.36	0.36	sack
Durio zibethinus	fruit	0.36	2.16	1.44	fruit
Gliricidia sepium	branches	8.64	8.64	8.64	car
Gmelina arborea	timber	10.8	14.40	12.96	m^3
Hylocereus undatus	fruit	0.58	1.44	1.01	kg
Lansium domesticum	fruit	0.07	0.36	0.25	kg
Mangifera indica	fruit	0.07	0.72	0.36	fruit
Metroxylon sagu	sago	1.80	1.80	1.80	sack
Musa spp.	fruit	0.07	0.36	0.22	hand
		1.44	2.30	1.80	bunch
Persea americana	fruit	0.14	0.50	0.36	fruit
Piper nigrum	dried fruit	5.04	6.12	5.40	kg
Pogostemon cablin	dried aerial part	0.22	0.36	0.32	kg
Solanum melongena	fruit	0.14	0.16	0.15	fruit
Syzigium aromaticum	dried flower buds	5.76	10.08	8.64	kg
Vigna unguiculata	fruit	0.14	0.17	0.14	pack
Zea mays	cob	0.07	0.18	0.09	spike

*USD/unit.

5.4.3. Gross margin per ha

The gross margin per ha ranged from -107 USD/year (-1,480,000 IDR/year) on a newly replanted farm with a lot of young cocoa trees that were not ready to produce fruit, to 4,810 USD/year (66,808,000 IDR/year) on a highly productive farm. The average gross margin per ha was 1,699 USD/year (23,596,988 IDR/year).

Even though the average gross margin per ha was higher in Kalukku than in Simboro (Table 10), there was no clear correlation found between district and gross margin per ha (σ=0.0822). The correlation between the gross margin per ha and participation in the GP-SCPP program was also not found (σ=0.0578).

Table 10. Average gross margin per ha.

	Average gross margin (USD/ha)		
	Mamuju	**Simboro**	**Kalukku**
All farms	1,699	1,586	1,781
GP-SCPP	1,744	1,649	1,823
Non GP-SCPP	1,595	1,385	1,700

5.5. Impact of increased agrobiodiversity on farming practices and farm economic performance

Agrobiodiversity was found to influence some of the farming practices, especially using chemicals against pests and diseases. A moderately strong negative correlation (σ= -0.3172) was found between the costs spent on pesticides (herbicides, insecticides and fungicides) and agrobiodiversity (Figure 26).

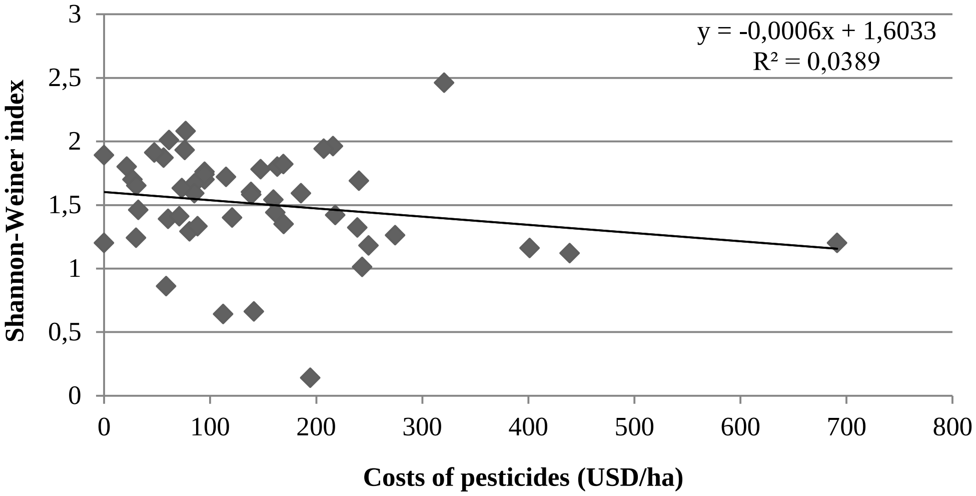

Figure 26. Correlation between costs spent on pesticides per farm size (USD/ha) and agrobiodiversity among selected farmers (n=50).

There was no clear correlation found between the amount of fertilizers used (costs spent on fertilizers) and agrobiodiversity (σ= -0.0822). Agrobiodiversity was also not found to influence yield. The correlation coefficient between cocoa yields per ha and agrobiodiversity was 0.0718.

The correlation between farm economic performance and agrobiodiversity (Figure 27) was found to be positive and moderately strong (σ=0.3607).

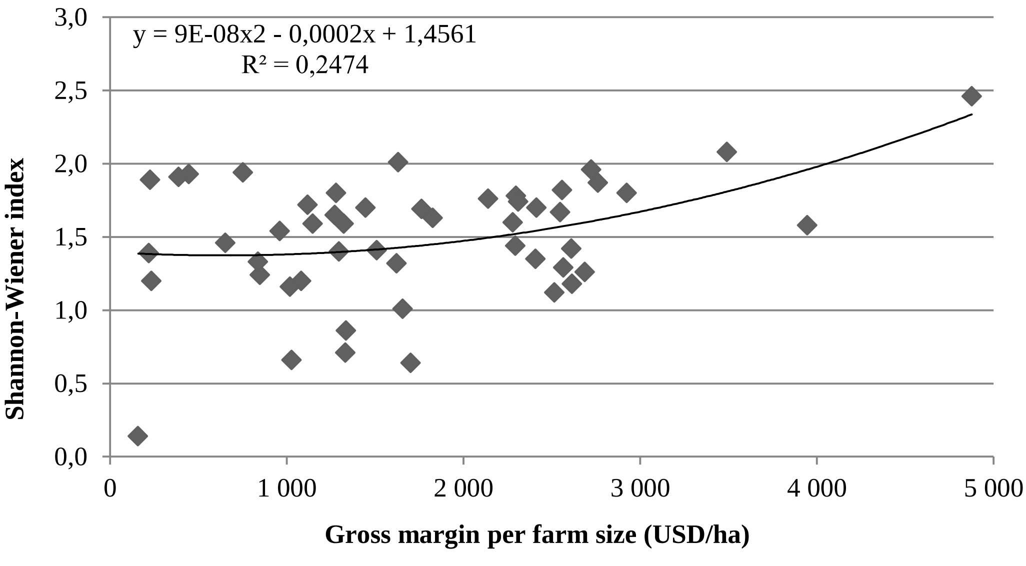

Figure 27. Correlation between economic performance and agrobiodiversity among selected farmers (n=50).

6. Discussion

In total, 64 useful plant species from which 35 were trees and palms was found on cocoa farms in Mamuju. The number of species was lower than that reported by different studies of cocoa agroforests. However, since every study used different methodology, it is hard to compare the results. For example, Jagoret et al. (2013) found a significantly higher number of non-cocoa species (122) on cocoa farms in Cameroon, however, they used a larger sampling plots (1000 m²). Ahado (2017) identified 41 tree species in 5 25×25 m sampling plots in cocoa agroforests in Ghana. Bisseleua et al. (2013) reported 102 tree and 260 herbaceous species during their survey of 16 20×30 m cocoa agroforest plots in Cameroon.

In Mamuju, the most popular uses for non-cocoa species mentioned by farmers included household consumption of non-woody species and products for selling, followed by cocoa tree shading, medicinal use and providing construction material and fodder for animals. Jagoret et al. (2014) recorded the same two main use categories. However, products for selling was mentioned by farmers in Cameroon more often than home consumption compared to the farmers in Mamuju. The third most important category of use mentioned by Jagoret et al. (2014) was soil fertility preservation and enhancement. In comparison to that, only 5% of plant species in Mamuju was reported by farmers to have such a function. Such a low percentage does not correlate with the species abundance. Since the most abundant species was *Gliricidia sepium*, a nitrogen fixing tree from the Famaceae family that enhances soil fertility, the low citation of use for soil fertility enhancement by farmers reflects the lack of knowledge of this topic among the interviewed farmers.

The preferences for particular plant species were not consistent among the interviewed farmers. The two main factors influencing farmers' preferences were location (terrain and distance to market) and religion. According to Nunoo et al. (2015) species choice as well as the average number of tree species cultivated vary according to cultural tradition and ethnic group, age of farms, proximity to markets, and the farming system intensity.

The mean Shannon-Weiner index varied significantly among the studies looking into the biodiversity of cocoa agroforests. The variation is caused mainly by the different methodologies applied, which makes the results not directly comparable. Jagoret et al. (2014) for example measured the mean Shannon-Weiner index 2.42. The Shannon-Weiner index measured by Bandanaa et al. (2016) varied between 0.76 and 0.81, however, they applied different sampling methods for enumerating the herbaceous plants.

Even though sustainable agriculture projects, including GP-SCPP, has biodiversity protection as one of their goals, the farmers participating in GP-SCPP were not proven to maintain significantly higher levels of agrobiodiversity on their farms. This lack of difference could be caused by long tradition of cultivation of various crops in agroforestry systems among the smallholder farmers in Sulawesi. Furthermore, the research revealed that the relationships between farmers are usually very close and farmers from the same village or group share information and apply similar practices and plant similar shade trees and other non-cocoa species regardless of their participation in GP-SCPP.

The levels of agrobiodiversity also slightly differed in the two visited districts. This phenomenon can be explained by the fact that some parts of Simboro were quite secluded, especially villages and farms off the main road that have restricted access to markets in other villages. Farmers and villages in these places were then forced to be more self-sufficient. This theory also supports the study of Nunoo et al. (2015) that lists proximity to markets as one of the factors influencing the average number of tree species per ha.

The results also suggested that female farmers are more inclined to have more diverse farms than male framers. One of the possible reasons for this can be the simple fact that women are responsible for cooking in the household and taking care of the children. Therefore, they keep more plant species which they use for cooking, as a condiment or as a medicine. Similarly, Howard-Borjas (2001) thinks that women, due to their domestic tasks such as cooking, sustain an intimate relationship with plants and thus play an important role in plant biodiversity conservation.

Results showed that increased levels of agrobiodiversity do not influence cocoa yields. Also Kieck et al. (2016), who studied the effect of plant diversity on cocoa yields in the Peruvian Amazonia found no correlation of yield per hectare or total fruit set with plant alpha diversity. Deheuvels et al. (2012) also observed that changes in the vegetation structure of cocoa farms did not influence the overall cocoa yield. However, this research compared the cocoa yields only with a density of *Musa* sp. cultivated in cocoa farms. Koko at al. (2013) says that the vigour and yield of cocoa is highly correlated with light exposure thus decrease when shade trees are planted. His results showed that cocoa cultivated in monocultures had four times higher yields than cocoa intercropped with orange or avocado trees (both at 44 trees/ha). A negative correlation between the number of shade trees and cocoa yields was found also by Nunoo et al. (2015). Different results were found by Vebrova et al. (2014) which showed a slight positive but not significant correlation between yields and number of shade trees. They also did not find any significant correlation between cocoa yields and tree species richness diversity.

On average, 550 kg of fertilizers were used on cocoa farms, which averages to 0.69 kg/tree/year. The amount of fertilizers was lower than that recommended by Swisscontacts' GAP manual (300g/tree applied 3 times/year). The type of fertilizer used is also problematic. Even though cocoa is a crop that demands quite a high amount of phosphorus for fruit formation (Wood & Lass, 1985), the main type of fertilizer used, and often the only type, was urea. The overall cocoa yields were correlated to the amount fertilizer used. However, the correlation was not very strong (σ=0.2264). According to Uribe et al. (2001), the weak effect of fertilization on the yield of shaded cocoa is caused by less intense photosynthesis. In comparison to shaded cocoa, the cocoa grown under sunlight has more intense photosynthesis thus the conversion of fertilizers is higher and faster.

Mean yields were about 120 kg/ha higher on GP-SCPP farms The higher productivity of farms in GP-SCPP indicates that rechniques taught during farmer field schools are being adopted. GP-SCPP has only been implemented in the last three years (since 2015), meaning that it is possible that yield can continue to increase as the application of GAP increases and the newly planted and grafted trees starts to yield.

The results revealed two main reasons for better economic performance of farms with higher levels of agrobiodiversity. These were revenues from sold non-cocoa products and reduced costs spent on pesticides. The revenues from non-cocoa product represented up to 41% of farm revenues. The true contribution to livelihood of farmers and their families is however believed to be much higher. According to Cerda et al. (2014) the non-cocoa agroforestry products are as important in terms of family benefits as cocoa. They provide valuable products for domestic consumption using only family labor, thus only very small amount of cash amounts.

The lower costs spent on pesticides suggests that farms with higher agrobiodiversity levels had lower incidence of pathogens. Biesseleua et al. (2013) found out that the amount of mirid bugs and cocoa pod borers, two serious pests of cocoa, decreased with increased shade index. This was caused by higher numbers of predators (spiders, wasps and ants) present in more diverse systems. A study conducted by Kieck et al. (2016) showed inconsistent relations between agrobiodiversity level and infestation rate. However, their research only studied the relationship between alpha diversity in the understory and infestation rates of fungal pathogens. Similarly, research of Jazeer et al. (2017) showed that diversified systems were more cost-effective (BCR) and profitable (net revenue), especially because reduced costs.

A major factor that contributes to gross margin per hectare is the market price for cocoa. In Indonesia, cocoa farmers are subject to an open market as opposed to government regulated cocoa prices that can be seen in Ghana (Vigneri & Kolavalli, 2018).

The price for cocoa at a local level is influenced by the farmers' proximity to supply chain off-takers that are further upstream in the supply chain, competition between traders, the farmers' negotiation skills, certification, and others. While increased farm biodiversity may improve farmers' gross margin in this current economic climate, the difference may not be significant enough to offset the risks of a major price shock from the local or global market.

To reduce economic vulnerability among smallholder cocoa farmers, farmers need better access to the market. Currently, many farmers in Sulawesi are selling their individual beans to multiple middlemen that each profit from a margin, and thus reducing the price paid to farmers. Farmers can gain better access to the market by forming producer groups for greater purchasing power. Well-organized farmer groups and cooperatives can pool their beans together and sell directly to exporters.

Furthermore, farmers need to receive higher prices for higher quality cocoa. Currently, the price difference between fermented and non-fermented beans is minimal to non-existent. For farmers to produce higher quality products, there needs to be economic incentive, otherwise farmers have no reason to pay attention to quality standards. Even selling certified cocoa is not always strong enough incentive to encourage farmers to cultivate sustainably. Cocoa sector stakeholders should come together to discuss how this issue can be overcome.

Conclusions

The research found that cocoa farmers in Mamuju cultivated quite high number of various non-cocoa plant species. The most preferred species were generally multipurpose. A common feature of most of these species was easy propagation and cultivation and fast growth, Even though the preferred non-cocoa species had some common features, farmers' preferences for non-cocoa species differed between the two districts of Kalukku and Simboro, and even between some villages.While some frequently occurring plants, such as those from the Fabaceae family, have a positive effect on the soil nutrient content, very few farmers were aware of this.

Even though the farmers participating in GP-SCPP were expected to cultivate higher levels of agrobiodiversity on their farms than those not participating in GP-SCPP, no clear correlation between participation in the GP-SCPP program and the level of agrobiodiversity was found. As this study was done on a limited number of farms, more research involving a higher amount of farms should be done to evaluate the impact of GP-SCPP on farm agrobiodiversity in West Sulawesi.

The positive correlation found between the gross margin per hectare and agrobiodiversity proved the hypothesis that increased agrobiodiversity is beneficial for the farm’s economic performance. The agrobiodiversity level was found to have neither positive nor negative impact on cocoa yields. The higher gross margin per hectare of farms with higher levels of agrobiodiversity was caused partly by the revenues from non-cocoa products, and partly by the lower need for pesticide use which reduced the farm variable costs.

Despite this finding, cocoa farmers still remain vulnerable to price fluctuations, as cocoa production contributes to a majority of their income. Smallholder farmers are particularly at risk of volatile price shock. Even if the smallholders' cocoa trees produce well, their non-cocoa produce sales and reduced pesticide use would not necessarily offset the impact of price fluctuations and could leave the families in a worse economic position.

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Appendices

List of the Appendices:

Appendix 1: Questionaire.

Appendix 2: Plant survey.

Appendix 1: Questionaire.

21 24/4/17 GP-SCPP

Nama	RAHMAT	Bergabung sejak	2014
No. ID	[redacted]	Pelatihan yang pernah diikuti	GAP, GNP
Usia / lahir	1960	Sertifikasi	No
jenis kelamin	MALE	Nama Desa	Kalukku
pendidikan terakhir	TAMAT SD	Laus kebun	1
pekerjaan lain	No	Jumlah pohon	800

0. Apakah anda menyimpan catatan perhitungan belanja?

   Tidak

1. Berapa jauh jarak kebun coklat dari rumah anda?
   - a. disamping rumah
   - b. kurang dari 500m (150 m)
   - c. 500m – 1km
   - d. lebih dari 1km

2. Biasanya pergi ke kebun naik apa? jalan

3. Berapa hari dalam satu minggu anda pergi ke kebun? 6

4. Apakah ada yang membantu dalam pekerjaan di kebun?
   - 4.1. Kalau ya, siapa yang membantu?
     - a. Keluarga istri
     - b. Teman
     - c. Petani lain
     - d. Pekerja 2 orang
   - 4.2. Berapa hari dalam satu tahun mereka membantu? 2x y / 6 days
   - 4.3. Berapa gaji mereka per hari 50,000 IDR / hari

5. Apakah anda menggunakan pupuk organik? Ya
   - 5.1. Jenis pupuk organik apa yang anda gunakan? pupuk kambing
   - 5.2. Darimana anda mendapatkan pupuk organik tersebut? sendiri
   - 5.3 Berapa banyak dan seberapa sering anda menggunakannya? cca 4x/y
   - 5.4. Berapa biaya yang anda keluarkan untuk membeli/membuat puput organik tersebut? —0—

6. Apakah anda menggunakan pupuk kimia? Ya
   - 6.1. Jenis pupuk kimia apa yang anda gunakan? NPK, urea (1:1)
   - 6.2. Dimana anda membeli pupuk kimia tersebut? loc. Prod. Kalukku
   - 6.3. Berapa banyak dan seberapa sering anda menggunakannya 2x 0,25 kg NPK, 2x 0,25 urea per pohon
   - 6.4. Berapa banyak biaya yang anda keluarkan per tahun untuk pupuk kimia tersebut?

→ 800 pohon = 800 · 0,5 + 800 · 0,5 = 400 kg NPK + 400 kg urea

urea 180 000 / 2

NPK 125 000 / sac (0,5 2) = 250 000/2

→ 720 000 + 1000 000 = 1720 000 IDR

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7. Apakah anda menggunakan herbisida? Ya

7.1. Jenis herbisida apa yang anda gunakan? Gramoxone

7.2. Dimana anda membeli herbisida tersebut? loc. m. kalikan

7.3. Berapa kali dalam satu tahun anda menggunakan herbisida? 4x

7.4. Dosis apa yang anda pakai? 150ml/app

7.5. Berapa banyak biaya yang anda keluarkan per tahun untuk herbisida tersebut? 4 x 115000 = 460000 IDR/y

8. Apakah anda menggunakan pestisida? Ya

8.1. Jenis pestisida apa yang ada gunakan? Starban

8.2. Dimana anda membeli pestisida tersebut? —"—

8.3. Berapa kali dalam satu tahun anda menggunakan pestisida? 12x 500g/app

8.4. Dosis apa yang anda pakai? 85 000/250 g

8.5. Berapa banyak biaya yang anda keluarkan per tahun untuk pestisida tersebut? 85 000 x 2 x 12 = 2040 000 IDR/y

9. Apakah anda menggunakan fungisida? Tidak

9.1. Jenis fungisida apa yang ada gunakan?

9.2 Dimana anda membeli fungisida tersebut?

9.3. Berapa kali dalam satu tahun anda menggunakan fungisida?

9.4. Dosis apa yang anda pakai?

9.5. Berapa banyak biaya yang anda keluarkan per tahun untuk fungisida tersebut? Ø

10. Alat apa saja yang anda pakai untuk menggunakan semua produk kimia tersebut? tank

10.1. Dimana anda membeli peralatan tersebut? kalikan

10.2. Seberapa sering anda harus mengganti (Membeli yang baru)? 3-5y

10.3. Berapa harga peralatan tersebut? 350 000 IDR/tank

11. Apakah anda memakai pengaman pada saat menggunakan produk kimia? Ya

11.1. Alat pengaman apa saja yang anda gunakan? mask, helm, long sleeves

11.2. Dimana anda membeli peralatan tersebut? kalikan

11.3. Seberapa sering anda harus mengganti (Membeli yang baru)? 1x3 m (mask

11.4. Berapa harga alat pengaman tersebut? mask 10000 IDR/5pc

12. Apakah anda menanam pohon baru tahun lalu? Ya

12.1. Berapa banyak? 20

12.2. Dimana anda mendapatkan bibitnya? his own

12.3. Berapa harga 1 bibit? Ø

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13. Apakah ada pohon yang di- sambung samping (tempel) tahun lalu? Ya

13.1. Berapa banyak? ~ 50

13.2. Dimana anda mendapat bahan/alat sambung samping (tempel) tersebut?

13.3. Kalau anda membelinya, berapa harganya? → Ø

14. Seberapa banyak panen yang anda hasilkan tahun lalu (dalam kilogram)?

a. Panen trek (panen sedikit)

b. Panen biasa (panen sedang) 1 200 000 kg

c. Panen raya (panen banyak)

15. Apakah anda menjemur biji kakao sebelum dijual? Ya

15.1. Kalau ya, berapa lama anda menjemurnya? 5 hari

15.2. Alat apa saja yang anda gunakan untuk pengeringan? terpal

15.3. Berapa biaya yang dikeluarkan untuk proses pengeringan biji kakao tersebut? 100000 IDR/pc

16. Apakah anda melakukan fermentasi biji kakao sebelum dijemur? Tidak *

16.1. Kalau ya, berapa lama? Ø

16.2. Alat apa saja yang anda gunakan untuk proses fermentasi?

16.3. Berapa biaya yang dikeluarkan untuk proses fermentasi tersebut? Ø

* no buyer for ferm. (no extra price)

17. Pada siapa anda menjual biji kakao?

a. Pedagang pengumpul di kampung

b. Pedagang pengumpul di kecamatan

c. Pedagang kabupaten/exportir

d. Kelompok petani

18. Apakah anda mengantar biji kakao sendiri? Ya

18.1. Jika ya, berapa jarak dari rumah anda? from door

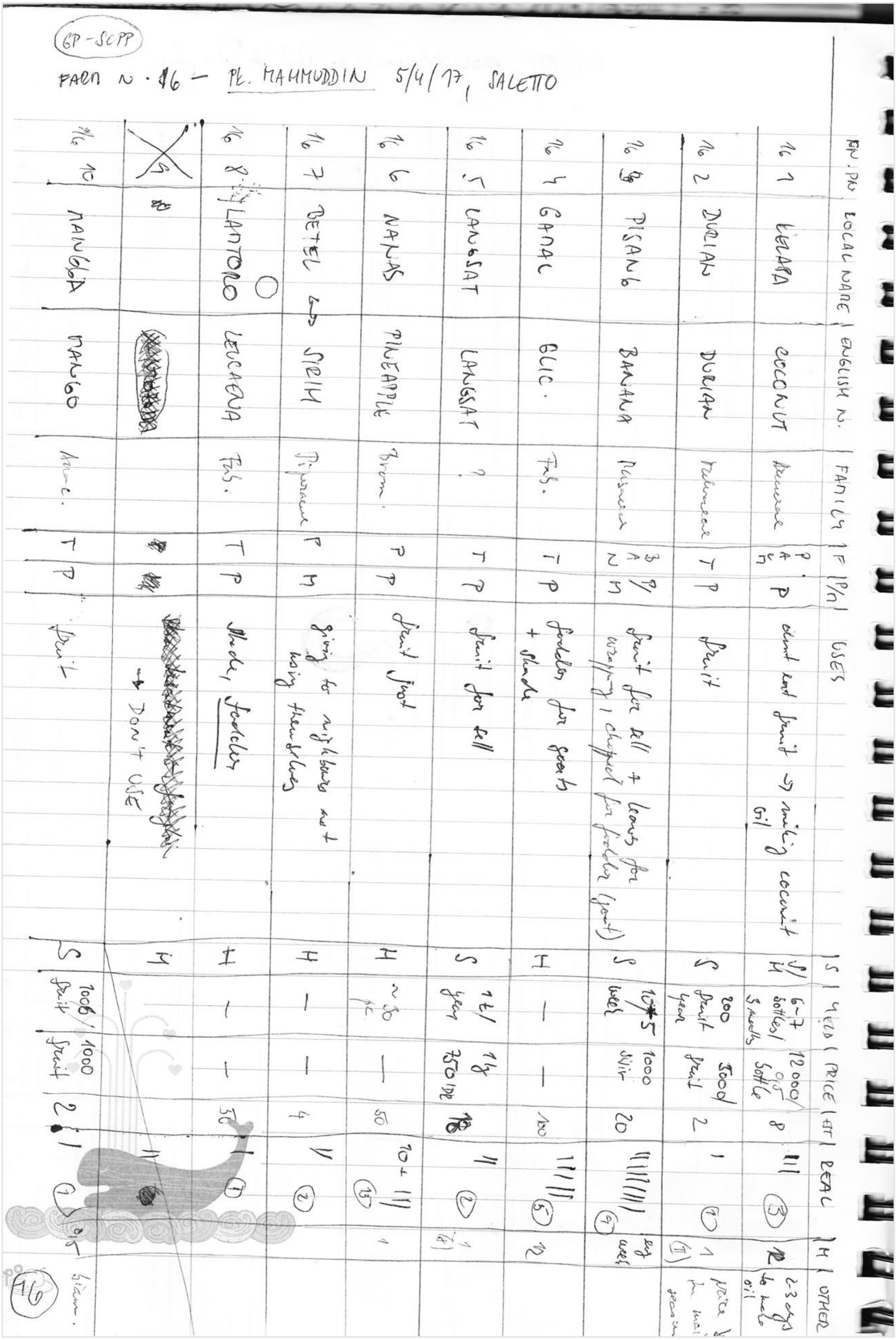
18.2. Kendaraan apa yang digunakan untuk mengantar bijij kakao tersebut?

19. Berapa harga biji kakao per kilo? 32 000 IDR/kg (25 – 38 000)

20. Apakah ada tambahan biaya lagi yang anda keluarkan tahun lalu pada kebun kakao ini?

Tidak Ø

Appendix 2: Plant survey.



GP-SCPP

FARM N. 16 – PL. MAHMUDDIN 5/4/17, SALETTO

FN.	PN.	LOCAL NAME	ENGLISH N.	FAMILY	F	P/M	USES	S	YIELD	PRICE	HT	REAL	M	OTHER
16	1	KELAPA	COCONUT	Arecaceae	PAWN	P	drink and fruit → making coconut oil	S/H	6–7 bottles/3 months	12 000/0,5 bottle	8	III (3)	R	2-3 days to make oil
16	2	DURIAN	DURIAN	Malvaceae	T	P	fruit	S	200 fruit year	5000/fruit	2	I (1)	1 (II)	price [illegible] in main season
16	3	PISANG	BANANA	Musaceae	BAN	P/M	fruit for sell + leaves for wrapping, chopped for fodder (goat)	S	10-15 week	1000 sisir	20	IIIIIIIII (9)	every week	
16	4	GAMAL	GLIC.	Fab.	T	P	fodder for goats + shade	H	–	–	100	IIIII (5)	12	
16	5	LANGSAT	LANGSAT	?	T	P	fruit for sell	S	1 t/year	1 kg 7500 IDR	18	II (2)	1 (8)	
16	6	NANAS	PINEAPPLE	Brom.	P	P	fruit just	H	~ 30 pc.	–	50	10 + III (13)	1	
16	7	BETEL →	SIRIH	Piperaceae	P	M	giving for neighbours not using themselves	H	–	–	4	II (2)		
16	8	LAMTORO	LEUCAENA	Fab.	T	P	shade, fodder	H	–	–	50	I (1)		
~~9~~			[illegible]				[illegible] → DON'T USE	H				II		
16	10	MANGGA	MANGO	Anac.	T	P	fruit	S	1000/fruit	1000/fruit	2	I (1)	0,5	5 km.

(16)