TREE COMMUNITY COMPOSITION AND STRUCTURE OF CACAO (*THEOBROMA CACAO* L.) BASED AGROFORESTRY IN WEST SUMATERA, INDONESIA

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Abstract – *The aim of this study is to obtain basic descriptive account of structure and floristic composition of cacao based agroforestry in conserving tree species diversity in West Sumatera. An analysis of the composition and structure of three types of cacao based agroforestry system (AFS) [cacao - rubber (CR), cacao – coconut (CC) and cacao multistrata (CM)] was conducted in April to June 2017. Data collection was done by using quadrat method of 20 x 20 meter plots with a total of 6 plots on each types of AFS. Herbarium specimens were collected and identified. Among all types of these AFS, CC was the most diverse floristically (H' = 1.02) with the highest total of species (10 species), followed by CM (9 species) and CR (7 species). CM has the highest tree density of 1108 trees per ha and the highest total of basal area (30.53 m²). We also did a comparison of the floristic composition of cacao based AFS with the nearest natural forest from previous study. There was a large decrease in the number of non-cocoa tree species from natural forest to AFS, from 139 to 6-9 species. The only native tree species found both in the forest and AFS is Pterospermum javanicum Jungh. It is concluded that three types of cocoa based AFS in West Sumatera were floristically different with natural forest.*

Keywords: *cacao based agroforestry, community structure, tree composition, tree species diversity*

Introduction

Agroforestry System (AFS) is one of the best approaches to reduce pressure on natural forest while still meeting local economic needs (Michon and de Foresta 1996, Nair 1998, Jose 2009). ICRAF (1993) defined agroforestry as a system and technology of land-use where annual woody plants (trees, palms, bamboo, *etc.*) are planted in unit of land management together with crops and or animals in the form of spatial or time management and in which interaction of ecology and economics among the components takes place. In addition to providing economic benefits from the production of crops, AFS is able to provide environmental services such as carbon storage services. Therefore, AFS is recognized as

an approved activity in a wide range of Land-use, Land-use Change and Forestry (LULUCF) based carbon market such as regulated carbon market (CDM), REDD+ and Voluntary Carbon Markets (VCM) (Murdiyarso and Herawati 2005, Angelsen & Wertz-Kanounnikoff 2010, Kollmuss *et al.* 2008, Asare 2014).

One of the most common commodity crops grown through AFS approach is cocoa (*Theobroma cacao* L.). Cocoa originally grows in tropical rain forests as an under shade plant type. In South America, cocoa is traditionally grown under the canopy of older primary forests, locally called *cabruca* (Sommariba *et al.* 2013). In addition to being grown under the forest canopy, cocoa is also grown under special shade tree from leguminosae or fruit trees and timber

with economic value as found in Sulawesi, Indonesia (Rajab *et al.* 2016).

In Indonesia, cocoa beans are mostly produced in six provinces, i.e. South Sulawesi, Central Sulawesi, Southeast Sulawesi, West Sulawesi, North Sumatra and West Sumatra. West Sumatra develops small scale cocoa agroforestry known as *parak*. Pasaman and Padang Pariaman Regency are the two highest cocoa producer region in West Sumatera. Pasaman is dominated by a multistrata cocoa-based AFS and cocoa-based AFS grown under rubber trees (*Hevea brasiliensis* Willd. ex A.Juss.). Padang-Pariaman is dominated by cocoa-based AFS grown under coconut (*Cocos nucifera* L.). Previous study has been done related to cocoa based AFS potential in sequestering carbon in West Sumatera (Santhyami *et al.* 2018)

Figure 1. Research locations in West Sumatera, Indonesia: CR (Cocoa – Rubber), CM (Cocoa Multistrata), CC (Cocoa Coconut)

A better knowledge of basic ecological information, including floristic composition of AFS is necessary for development of sustainable forest management and conservation. The objective of the present study is to obtain basic descriptive account of the structure and floristic composition of cacao based agroforestry in West Sumatera in conserving tree species diversity.

Materials and Methods

1.　Study Area

The study was conducted in April – June 2017 in Nagari Simpang, Simpati Subdistrict, Pasaman Region for multistrata cocoa-based AFS (CM) and cocoa-based AFS grown under rubber (*H. brasiliensis*) (CR) and Sungai Geringging, Padang Pariaman Region, West Sumatera for cocoa-based AFS grown under coconut (*C. nucifera*) (CC) (Fig. 1).

Nagari Simpang has an area of ± 49.496 ha with an altitude of 100-453m above sea level. Temperature ranges between 27-30^0 C with an average rainfall of 324.3 mm year^{-1}. Topography of Nagari Simpang is a plain surrounded by hills of natural forest. Types of soil in Pasaman are *litosol* and *podzolic*. From all of total area, 7/10 is forested area, the largest potential of Nagari Simpang. Besides the forest, Nagari Simpang managed 363 ha of paddy fields and 475 ha of farming land. Nagari Simpang has a forested area managed by local community. The forests are customary land (*hutan adat*).

Sungai Geringging is one of 17 subdistricts in Padang Pariaman with an area of about 99.35 km2. The average temperature is 25.49^0 C and relative humidity is 85.58%. The hottest temperatures fall in February, while the lowest in September. The overall average rainfall for Padang Pariaman Region in 2007 was 368.4

mm/year with an average wind speed of 2.14 knots hour[-1]. The topography of Sungai Geringging is hilly area with an altitude of 25m above sea level. Soil types are *alluvial*, *podzolic* and peat. The population of Sungai Geringging is about 25.815 people. Of the total population, 70% of them are farmers.

2. Data collection

Data collection was done by using quadrat method of 20 x 20 meter plot with a total of 6 plots on each types of AFS (Cox 1967, Mueller-Dombois and Ellenberg, 1974, ForestWorksISC 2014).

Herbarium specimens for each species within the plot were collected and identified at Herbarium Bogoriense, Research Center for Biology−LIPI in Cibinong, Indonesia. The identity and nomenclature of each tree species followed the *Tree flora of Indonesia: checklist for Sumatera* (Whitmore and Tantra, 1986) and *Flora Malesiana* (Steenis *et al.,* 1948-2013).

3. Data analysis

Important Value (IV), the sum of Relative Density (RD), Relative Frequency (FR) and Relative Dominance (RDo), were calculated based on Cox (1967) and Mueller-Dombois and Ellenberg (1974). The index of species diversity (H') was calculated by using Shannon Weiner Index (SWI) (Shannon and Weiner 1963).

Result and Discussion

The results of this study shows the community structure of the three most common types of cacao-based AFS in West Sumatra province, namely; (1) cacao-based agroforestry with rubber as the main shade tree (CR), (2) cocoa-based agroforestry with multiple species of shade trees (called multistrata) (CM), (3) cocoa-based agroforestry with coconut as the main shade trees (CC). The first two AFS were commonly found in the lowland areas of Pasaman Regency while CC were commonly found in coastal areas including Pariaman Regency. Although the main shade trees were

rubber or coconut, most farmers also planted a number of other trees as mixed commodities such as areca palms, durian, candlenut *etc*.

Table 1 shows a comparison of the composition of three types of cocoa-based AFS in West Sumatera. CC is the system with the highest number of tree species (10 species), followed by CM and CR (9 and 7 species respectively). CM has the highest number of individual trees per hectare (approximately 1100 stems).

Table 1. Composition of cacao based AFS in West Sumatera

AFS Type	No	Species	IV (%)	H'
Cacao - Rubber (CR)	1	*Hevea brasiliensis*	129.75	0.27
	2	*Tectona grandis*	10.45	0.05
	3	*Pterospermum javanicum*	7.88	0.04
	4	*Durio zibethinus* Murr.	6.53	0.03
	5	*Lansium parasiticum*	6.41	0.03
	6	*Musa spp.*	7.47	0.04
	7	*Theobroma cacao*	131.51	0.27
Total			**300**	**0.72**
Cacao Multistrata (CM)	1	*Annona muricata*	3.82	0.02
	2	*Areca catechu*	43.44	0.13
	3	*Aleurites moluccana*	48.21	0.14
	4	*Hevea brasiliensis*	82.26	0.19
	5	*Archidendron pauciflorum*	6.98	0.03
	6	*Durio zibethinus*	24.90	0.09
	7	*Lansium parasiticum*	8.73	0.04
	8	*Theobroma cacao*	81.65	0.19
Total			**300**	**0.82**

AFS Type	No	Species	IV (%)	H'
Cacao Coconut (CC)	1	*Areca catechu*	50.47	0.17
	2	*Cocos nucifera*	93.70	0.25
	3	*Archidendron pauciflorum*	3.79	0.02
	4	*Parkia speciosa*	8.12	0.05
	5	*Toona sureni*	11.29	0.06
	6	*Myristica fragrans*	4.12	0.03
	7	*Syzygium aromaticum*	13.01	0.07
	8	*Durio zibethinus*	3.99	0.03
	9	*Musa spp.*	34.82	0.13
	10	*Theobroma cacao*	76.68	0.22
Total			**300**	**1.02**

CM also scored the highest tree basal area of 31 m², followed by CC and CR at 27 and 21 m² respectively. The two most dominant species indicated by Important Values (IV) on each type of agroforestry are as follows; (1) cacao (131.51%) and rubber (129.75%) on CR, (2) rubber (82.26%) and cocoa (81.65%) on CM, and (3) coconut (93.70%) and cocoa (76.68%) on CC.

Groups of cacao-based AFS observed had varied diversity index. CC has the highest diversity index (H') of 1.02, followed by CM and cocoa-coconut cacao groups of 0.82 and 0.72 respectively. The evenness index of the three types of agroforestry is small, ranging from 0.27 - 0.36.

Fig. 2 shows the distribution of the number of trees individual in each type of AFS based on diameter groups. The majority type of trees in all three types of AFS are small trees with DBH of 10 - 19.9 cm. Only CC that have trees with DBH above 50 cm. Cocoa-based AFS has special characteristics according to the composition of the tree stand. On understory layer, land is dominated by cocoa stems, but on the higher strata, stands are represented by various types of shade trees such as native trees from remaining forest, natural timber trees, planted timber trees, fruit trees and special nitrogen fixing trees species such as *Gliricidia sepium* (Jacq.) and *Erythrina* ssp.
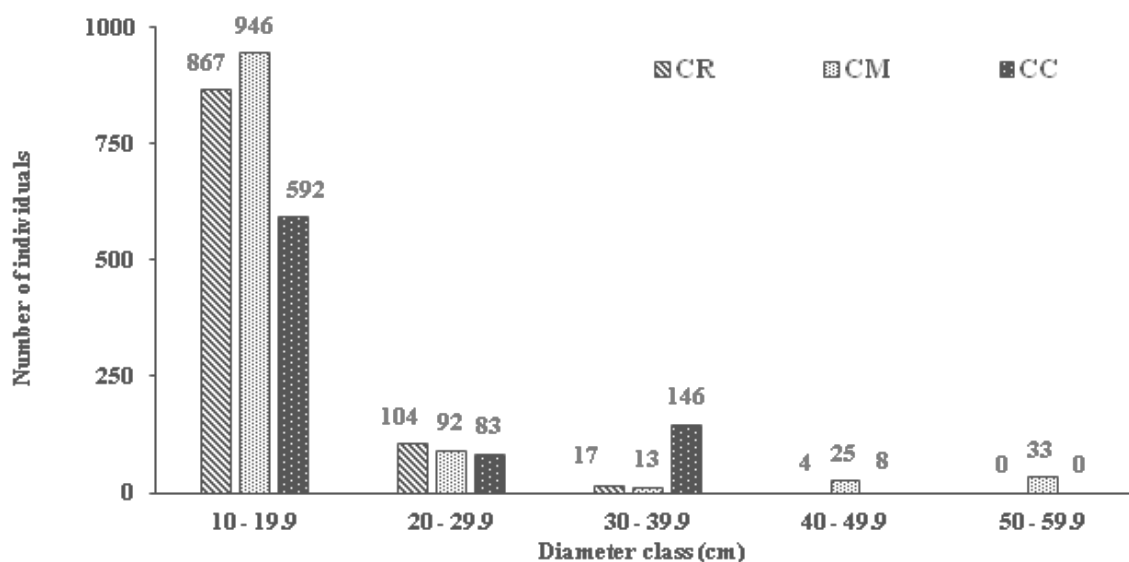

Figure 2. Number of trees individual based on diameter class

The cocoa-based AFS pattern in West Sumatra varies based on composition and density. The type of agroforestry in West Sumatra based on the Nair (1993) categories is agrisilviculture, a form of land use that combines seasonal plants with woody trees. Based on shade tree species (Rice and Greenberg 2000), the type of cocoa development in West Sumatra varies from a

non-shade system (monoculture), mixed with one main shade tree such as rubber and coconut and a multistrata cocoa system.

Pasaman and Padang Pariaman Regions are the two highest cocoa producing areas in West Sumatra. In Pasaman, cocoa farming is dominated by CM and CR types. In the early 1980s, farmers in Pasaman had developed rubber plantations. However, in the mid-1990s, rubber experienced a decrease in productivity and profitability so farmers began to grow cocoa as the main crop planted under the remaining rubber trees. Farmers chose cocoa because this commodity can be harvested within four to five years and produce throughout the year. In addition, cocoa prices tend to be stable in the market. Whereas in Pariaman, the community planted cocoa under coconut trees that had been planted decades before.

Although at the beginning of the study, terminology of CM was given as an agroforestry type with many shade tree species, but from the results of the study it was seen that the CC in Pariaman the highest number of species on

it. However, CM is still the group with the highest number of individual per hectare. When compared with other CM in Sulawesi, the tree density of CM in West Sumatra is lower (Table 2).

Management levels and production pressures affect the low number of individuals per hectare in West Sumatra. Basically, the planting of all three types of agroforestry in West Sumatra did not follow the rules of distance of cocoa planting in general. The community tends to plant cacao randomly in the remains of hedges under the shade of other existing trees. It can be seen from the lower amount of cocoa stem per hectare in West Sumatra compared to agroforestry in Sulawesi (Rajab *et al*. 2016).

In contrast to the density of cocoa trees, non-cocoa trees density with DBH ≥ 10 cm in cocoa-based AFS in West Sumatra is higher when compared to some other cacao-based AFS (Rajab et al. 2016, Bisseleua 2008) even higher than the Bukit Bandindiang natural forest as a the nearest natural forest to AFS location (Santhyami, *unpublished*).

Table 2. Comparison of cacao based AFS structure in two regions in Indonesia

No	Type of land use	Location	Total tree density (trees/ha)	Cacao density (stem/ha)	Basal Area (m²)	Diversity Index (H')	Source
1	Cacao - Rubber	Pasaman, West Sumatera	992	538	21	0.72	This study
2	Cacao - Coconut	Pariaman, West Sumatera	829	354	27.5	1.02	This study
3	Cacao multistrata	Pasaman, West Sumatera	1108	433	30.5	0.82	This study
4	Cakao multistrata	Lembah Kulawi, Central Sulawesi	1741	1384	34.6	0.45	Rajab *et al.* 2016
5	Cakao - *Gliricidia*	Lembah Kulawi, Central Sulawesi	1497	1047	13.8	0.31	Rajab *et al.* 2016

On CR and CM, non-cocoa tree is dominated by rubber, planted with an approximately distance of 5x5 m, while on CC, it is dominated by coconut trees and areca palms (Santhyami *et al.* 2018). Areca palm is commonly known by the community as a hedgerow plant.

The high density of total trees in cacao based AFS in West Sumatra is closely related to thinning factor. From the observations, farmers in all types of cacao based AFS in West Sumatra did not conduct thinning process although the age of cocoa had exceeded ten years. This shows the low level of intensity of agroforestry

management. Management and the level of shade are often correlated (Wade *et al.* 2010, Asare *et al.* 2018). Based on research by Stefan-Dewenter *et al.* (2007), cocoa planting can be economically valuable on the low density non-cocoa trees and thinning is proceeded.

Table 1 shows CR and CM were categorized to have a low tree diversity, while CC was a medium one. As comparison, nearest natural forest, Bukit Badindiang, was classified to have high diversity (Santhyami, *unpublished*). Cacao based AFS varied greatly in terms of species richness and composition depending on the level of management and history of land use. The decline in the number of non-cocoa tree species from natural forest to cacao based AFS was vast, (139 to 6-9 species). A report by Gradstein *et al.* (2007) at 0.25 ha of cacao based AFS in Indonesia found a decrease of an average of 21 species of non-cocoa trees in agricultural land with shade trees were coming from the remaining forest to 10 species on land with shade trees that were deliberately planted. This decline is in line with '*intensive young theory* (Intensive Young - YI) where plant diversity would be low on young (newly planted) agroforestry lands and/or on productive agroforestry lands with increasingly intensive levels of management (Stefan-Dewenter *et al.* 2007).

The result shows that the only native tree species found both in the forest and on cacao based AFS in West Sumatera was *P. javanicum* Jungh. The proportion of tree of native species as cacao shade trees generally will decrease with the increasing of land age, market access and intensity of land use. When farmers begin to increase production pressure on land, native shade trees originating from forest cover would be cut down or replaced with other species such as fruit trees which are generally not native to

the area (Gradstein *et al.* 2007, Sonwa *et al.* 2007). Latest studies has showed the advantages of choosing native shade trees instead of exotic shade. Ecological services of native shade trees on coffe based agroforestry is more eminent to exotic shade particularly on effect to yield of coffee, consistency in yield and cupping quality of coffee beans were much improved under native shade trees (Dhanya *et al.* 2014)

Another factor related to the limited type of non-cocoa trees in the composition of cacao based AFS in West Sumatra is the size of the land. Generally, cacao farming, both in Pasaman, Pariaman and other areas in West Sumatra, has traditionally been developed on a relatively limited land. Farmers with small land tend to grow trees selectively to meet their primary needs which causes low levels of diversity on their AFS (Deb *et al.* 2014).

Conclusion

Cacao – Coconut AFS (CC) appeared to be the most diverse cacao based AFS in West Sumatera with the highest total of species. Cacao multistrata (CM) has the highest tree density and total of basal area. There was a large decrease in the number of non-cocoa tree species from natural forest to AFS. Three types of cocoa based AFS in West Sumatera were floristically different with natural forest.

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