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Cocoa farming patterns for sustainability of Indonesia Lore Lindu National Park (LLNP)

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Abstract

This research assesses the effects of different patterns of cocoa farming at the margin areas of Lore Lindu National Park (LLNP) forest by estimating species richness, density of vegetation, biomass potential, litter production, litter decomposition rates and farming income. Research was conducted in the LLNP, Central Sulawesi, Indonesia. Five patterns of cocoa farming systems were considered: cocoa farming + mixed wood trees (agroforestry complex), cocoa farming + fruit trees (agroforestry simple), cocoa farming + candlenut trees (agroforestry simple), cocoa farming + teak trees (agroforestry simple), and monoculture cocoa farming. Five sample plots were made in each cocoa-farming pattern, sized 20 x 20 m for tree vegetation sampling. Subplots of 10 x 10 m, 5 x 5 m, and 2 x 2 m were used to sample vegetation at earlier growth stages. The results showed that using a pattern of cocoa + mixed wood trees (agroforestry complex) produced the highest biomass. A pattern of cocoa + candlenut gave the highest average income per year, but the pattern of cocoa + mixed wood trees did differ significantly from that using candlenut. It is suggested that cocoa farming with mixed wood trees (agroforestry complex) along the perimeter of the LLNP forest will support the sustainability in biodiversity, water catchment areas and disaster control.

Keywords: Cocoa farming patterns, biomass potential, income, sustainability, National Parks.
Abbreviations: LLNP_ Lore Lindu National Park; IVI_Importance Value Index; NA _ natural forest; AFC _ agroforestry complex; AFS _ agroforestry simple; MC _ monoculture cocoa; dbh _ diameter at breast height; TC _ total cost; TR _ total revenue; Mg _ Megagram.

Introduction

Increase in the human population size has implications for the space requirements necessary for the food production. Forest resources are often used to meet such needs because they provide primary material for human needs (lumber), as well as biophysical factors that can support the production of agricultural crops. Deforestation and conversion into agricultural land and plantations has become the biggest cause of forest and biodiversity losses (Beck et al., 2002).

Lore Lindu National Park (LLNP) in Central Sulawesi, Indonesia is an important conservation area, where has been a designated UNESCO Biosphere Reserve since 1977, and serves to maintain biodiversity in Sulawesi (Wardah, 2008). The area covers 229,000 ha and provides benefits not only to conservation of biodiversity, but also as a place of research and an area for ecosystem surveys. The marginal areas of the LLNP protected area include agricultural lands. These areas have shifted from forested to agricultural lands, rapidly over a small distance (Corre et al., 2006). Forest destruction in LLNP was estimated by (Laturadja, 2009). A 4.26% of the forest was classified as severely damaged and 1.78% or about 3,800 ha, of these were due to land being used for cocoa crops. In fact, the LLNP marginal areas have important function. They can support agricultural activity such as cash crops. At the end, farmers will not enter the forest and destroy the trees. Bismark and Sawitri (2007) stated that forest margin areas can economically support development of the people who are living nearby a forest.

There are various forms and patterns of land usage by the people who live at the margin areas of LLNP that have converted the forest cover. The research of (Wardah, 2008) revealed that the pattern of land usage at the margin areas of LLNP are generally forest garden or mix gardens between cocoa crops with various types of timber, as well as annual crops with slash-and-burn system.

Land biomass is an indicator of environmental quality that is widely used because it contains information about the amount of organic matter and carbon potential (Helin et al., 2014). The carbon content becomes indicator in assessing the potential of land fertility and its environmental economic (Kim, 2001). Conversion of forest to agro-ecosystem degrades organic matter content of the land through the process of increasing decomposition rate, which in turn, will increase the rate of carbon dioxide release (CO2) into the atmosphere (Barchia et al., 2007).

Land management on both agroforestry and non-agroforestry by the people creates various agro-ecosystem conditions. This is caused because of the differences in biomass potential that contains on land, as well as differences in physical environmental factors, which influence the biogeochemical cycles. The Litterfall is one of the important events in the mechanism or the biogeochemical cycles since become an intermediary media of organic and inorganic systems in an ecosystem. Nowadays, litterfall from various ecosystems increasingly becomes a concern by experts because it is regarded as a key component of the carbon cycles, nutrient cycles and energy transfer in the process of decomposition. Decomposition provides nutrients that will ultimately affect the growth and production of plants. This, in turn, will affect farm productivity and income. This research aims at assessing the pattern of cocoa farming at the margin of the LLNP to support the sustainability in biodiversity, water catchments areas and disaster control.

Results and Discussion

Species composition of vegetation

The composition of plant species is a floristic list of plant species that exist in a community (Koike, 2010; Guadarrama et al., 2012; Carim et al., 2015). The results showed the number of species, genera, and families of vegetation present in plots varied by land type, both at the tree level (height >1.5 m) and at the level of low seedlings/plants (Fig. 1).

A 73.5% decrease in species richness of trees (height >1.5 m) occurs when going from natural forest into agroforestry complex. Similarly, the genera richness is reduced by 57.8% and family numbers decrease by 47.8%. Going from an agroforestry complex site to an agroforestry simple site leads to an 88.9% decrease in the number of species, an 86.6% decrease in the number of genera and and an 82.6% in the number of families. Seedlings and low plants showed the decrease only between natural forests, agroforestry sites and monoculture cocoa land. The agroforestry complex and agroforestry simple were similar in all abundance measures. This is likely due to the emergence of low plants or seedlings influenced more by environmental factors and the treatments used by farmers than tree species.

The diversity of species we found in natural forests was higher than that found by Wardah (2008) in the highlands Besoa in the southern region of the LLNP, where 27-79 species were observed. Purwaningsih and Yusuf (2005) observed 87 species, 64 genera and 38 families in natural forests within lowland Pakuli area of western LLNP.

In natural forest, vegetation density (number of individuals per hectare) was relatively low at the tree level and successively increased at the level of poles and stakes. These distribution patterns are an expected and natural phenomenon that occurs in natural forest ecosystems. For the agroforestry land types, whether complex or simple, as well as for the monoculture cocoa land type, the highest density occurred at the level of poles. This reflects the fact that these land types were dominated by cocoa. The density of trees with dbh >10 cm in lowland climax forests in Indonesia, generally range from 400-600 trees/ha (Bratawinata, 1993). At the seedlings/low plants level, there was a tendency for higher densities in the cocoa monoculture land type compared to agroforestry land type and the lowest density occurred in natural forests.

Dominance and biodiversity

A diversity index is used to estimate the effects of a disturbance to the environment, or to estimate stages of succession and stability of plant communities in a location (Odum, 1996). Low diversity index values suggest a strong ecological pressure is present, either from biotic factors (e.g., competition among individual plants) or abiotic factors.

The Shannon-Wiener species diversity (H') reveals strong differences among the land types (Fig. 2). The diversity index value in natural forests was high (H '= 3.0 to 4.04) for all vegetative sizes. Agroforestry complex sites had a slightly decreased diversity index of 3.32 for trees and species diversity index value of <1.0 for poles and stakes. Tree species diversity decreased to <1 in agroforestry simple land type sites, and was 0 for monoculture croplands. The index value of diversity for seedlings/low plants was similar among land types, with a high value (H' = 3.0-4.0) in the natural forest and a medium diversity index (H' = 2.0-3.0) for agroforestry complex, agroforestry simple and monoculture cocoa land types.

The Importance Value Index (IVI) is a quantity that indicates the dominance of a species relative to other species in the community. The greater the IVI of species, the more important is its role in the community. At the level of trees (dbh >20 cm), the dominant species in the natural forest in all three replicate locations was *Lithocarpus elegans* Blume. *Calophyllum soulattri* Burm.f. was a second dominant species at locations 2 and 3 only, while *Palaquium obovatum* Griff. was dominant at location 2 only, *Syzygium adenophylla* Merr. and *Eucalyptus deglupta* Blume also showed dominance at location 1, and *Castanopsis accuminiatisima* (Miq). Rehder was dominant at location 3.

Dominant tree species differed among replicates in agroforestry land types. In the agroforestry complex land type of location 1, the dominant species were *Aleurites moluccana* (L.) Willd., *Theobroma cacao* L. and *Pterospermum celebicum* Miq. In location 2, beside *Pterospermum celebicum* Miq., *Magnolia condolii* (Blume) H. King and *Palaquium obovatum* Griff were dominant species. At the location 3, the dominant species again included *Aleurites moluccana* (L.) Wild. but also included *Octhomeles sumatrana* Jack and *Bischofia javanicum* Blume. In the other words, none of the dominant species in natural forests were dominant in agroforestry land types except *Palaquium obovatum* Griff types. The dominant vegetation types at all levels of the growth were types that have a great opportunity to remain in the concerned ecosystem, while the species that only exist on a specific growth level. It was unlikely to rest of the ecosystem (Wardah, 2008). The composition of species that only exist at one stage of growth are more susceptible to changes if there are disturbances.

For seedlings/low plants, the composition of the dominant species in natural forests differed for each replicate. At location 1, the dominant species were: *Psychotria* sp., *Erigeron sumatrensis* Retzdan, and *Ageratum hostorianum* Bleumink. At location 2, the dominant species were: *Pinanga cease* Blume, *Pilea* sp., and *Calophyllum soulattri* Burm.f. In location 3, the dominant species were: *Calamus* sp., *Syzygium* sp. and *Calophyllum* sp. Furthermore, none of the dominant vegetation types in the natural forest sites dominated in agroforestry complex or agroforestry simple land types. On land types other than natural forests, very few tree seedlings were observed and vegetation was dominated by low plants, herbs or weeds. The change in dominant plants with land type is likely because in the three land types outside of natural forest, cocoa cultivation practice created interference in the ecosystem, in the form of removing unwanted plants (weeds).

Estimation of biomass potential by agroecosystem type

All organic material in living vegetation, dead vegetation, (e.g., leaves, twigs, branches, and stems), in the soil (roots) and in litter was dried and recorded as dry weight per hectare.

Above-ground biomass

Above-ground biomass potentials were significantly different among farming patterns (Table 1). Total aboveground biomass varied among farming patterns, but cocoa farming +

Table 1. The above-ground biomass potential from farm sites with differing patterns of land use.

Farming patterns	Tree Biomass (Mg/ha)*	Seedlings/Low plants Biomass (Mg/ha)*
Cocoa + Mixed Wood Trees	307.44[e]	1.21[c]
Cocoa + Fruit Trees	209.36[d]	0.67[a]
Cocoa + Candlenut	141.50[b]	1.85[e]
Cocoa + Teak	155.30[c]	1.49[d]
Monoculture Cocoa	104.79[a]	0.84[b]

*Values followed by different letters in the same column were significantly different using Tukey's HSD $\alpha \leq 0.05$ test.

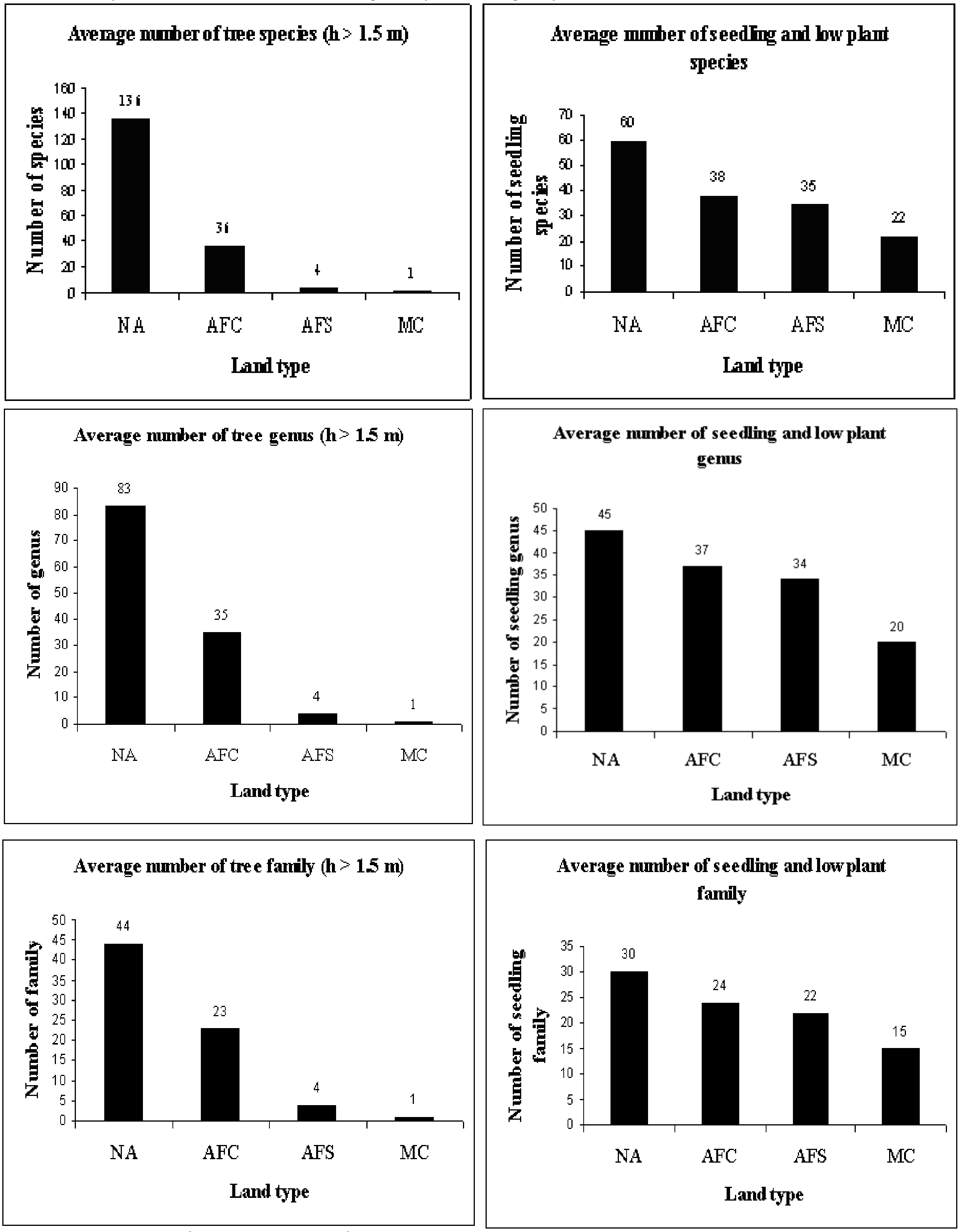

Fig 1. Average number of species, genera and families.

Table 2. Potential of below-ground biomass.

Farming pattern	Biomass of tree roots (Mg/ha)*	Biomass of cocoa roots (Mg/ha)*	Biomass of fine roots (Mg/ha)*
Cocoa + Mix Wood Tree	73.89^{e}	8.02^{a}	0.98^{bc}
Cocoa + Fruits tree	64.51^{d}	12.38^{c}	1.14^{c}
Cocoa + Candlenut	22.47^{b}	10.66^{b}	0.77^{ab}
Cocoa + Teak	39.15^{c}	9.36^{ab}	0.69^{a}
Monoculture Cocoa	17.28^{a}	16.72^{d}	0.88^{ab}

*Values followed by different letters in the same column were significantly different using Tukey's HSD $\alpha \le 0.05$ test.

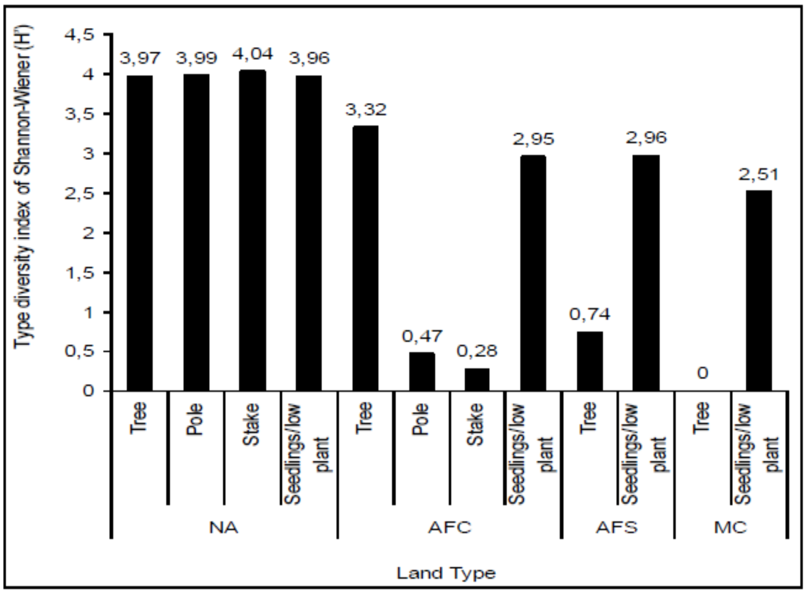

Fig 2. Shannon-Wiener (H') species diversity index by land type.

Table 3. Potential of litter biomass and necromass.

Farming pattern	Coarse litter biomass (Mg/ha)*	Fine litter biomass (Mg/ha)*	Necromass Biomass (Mg/ha)*
Cocoa + Mix Wood Tree	13.18^{d}	4.98^{d}	2.52^{e}
Cocoa + Fruits Tree	7.45^{a}	2.67^{a}	0.63^{a}
Cocoa + Candlenut	9.21^{b}	3.08^{b}	1.15^{c}
Cocoa + Teak	11.74^{c}	3.43^{c}	1.26^{d}
Monoculture Cocoa	8.42^{ab}	2.91^{b}	1.02^{b}

* Values followed by different letters in the same column were significantly different using Tukey's HSD $\alpha \le 0.05$ test.

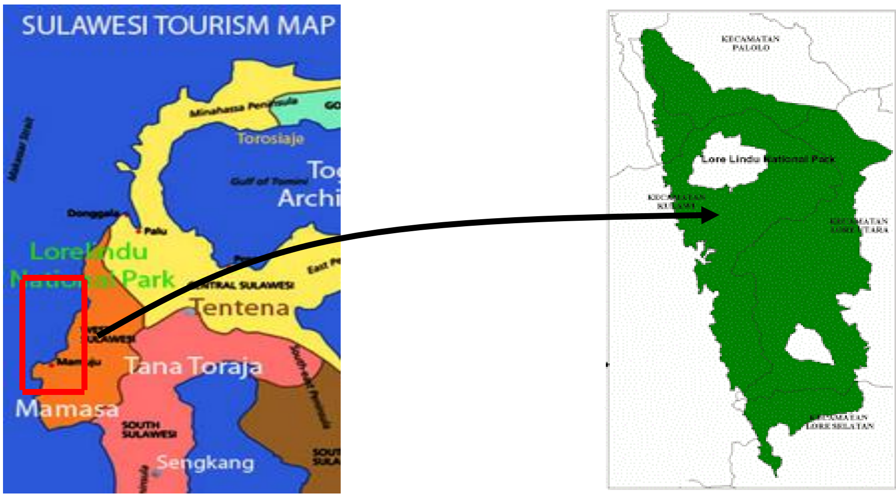

Fig 3. Location Lore Lindu National Park Central Sulawesi, Indonesia (red box, left) and the location of the research plots (white area, right).

Table 4. Litterfall production in various patterns of cocoa farming.

Farming pattern	Leaf fall (Mg/ha)*	Wood fall, stems, branches (Mg/ha)*	Reproductive organs fall (Mg/ha)*	Total (Mg/ha)*
Cocoa + Mix Wood Tree	5.54^{b}	1.64^{b}	0.87^{c}	8.05^{b}
Cocoa + Fruits tree	4.07^{ab}	1.10^{ab}	0.76^{abc}	5.93^{ab}
Cocoa + Candlenut	2.92^{a}	$0,65^{a}$	0.39^{a}	3.96^{a}
Cocoa + Teak	5.55^{b}	1.03^{ab}	0.79^{bc}	7.37^{ab}
Monoculture cocoa	3.08^{ab}	0.52^{a}	0.45^{ab}	4.05^{a}

*Values followed by different letters in the same column were significantly different using Tukey's HSD $\alpha \leq 0.05$ test.

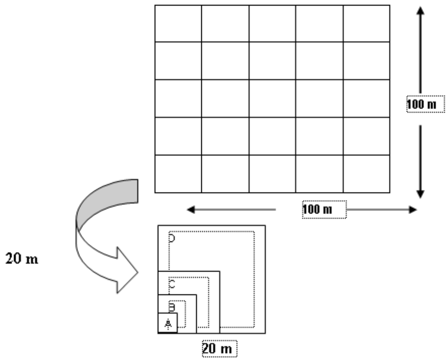

Fig 4. The diagram showing study design of plots, sub-plots and sub-swath of sampling areas. Vegetation analysis was done at the level of the tree (D), pole (C), stake (B), and seedling/plant (A) for each observed land type.

Table 5. Weight loss and litter decomposition rates.

Farming pattern	Weight Loss (%)*	Decomposition Rate* (k)
Cocoa + Mixed Wood Trees	78.58^{a}	0.0747^{a}
Cocoa + Fruits tree	78.98^{a}	0.0779^{ab}
Cocoa + Candlenut	83.07^{b}	0.0861^{c}
Cocoa + Teak	79.20^{a}	0.0786^{ab}
Monoculture cocoa	81.38^{ab}	0.0817^{bc}

*Values followed by different letters in the same column were significantly different using Tukey's HSD $\alpha \leq 0.05$ test.

Table 6. Farming income for various cocoa farming patterns.

Rank	Farming Patterns	TC[1] (IDR/ha/year)	TR[2] (IDR/ha/year)	Income (IDR/ha/year)*
1	Cocoa + Candlenut	6,025,740	22,373,740	$16,348,000^{a}$
2	Cocoa + Mixed Wood Trees	5,280,866	21,581,066	$16,300,200^{a}$
3	Cocoa + Fruit trees	5,781,044	22,019,044	$16,238,000^{a}$
4	Cocoa + Teak	6,104,940	22,057,140	$15,952,200^{b}$
5	Monoculture cocoa	6,348,810	21,953,810	$15,605,000^{c}$

[1]TC = total cost; [2]TR = total revenue

*Values followed by different letters in the same column were significantly different using Tukey's HSD $\alpha \leq 0.05$ test.

mixed wood trees had a higher biomass than all other farming patterns. Cocoa farming + mixed wood trees was a type of agro-ecosystem with a vegetation structure that still resembled natural forests because large trees are retained while vegetation at the level of saplings and poles are filled mostly by cocoa plants maintained by farmers. Biomass potential data suggest this type of farming pattern provides the best ecosystem in terms of producing biomass.

Below-ground biomass

Below-ground biomass is all roots found below ground, including fine roots (diameter <2 mm). The results of measurements of below-ground are shown on Table 2. Below-ground biomass potential of tree roots was significantly different among farming patterns. Total below-ground biomass revealed that the biomass of various farming patterns varied widely, but as with above-ground biomass, the cocoa + mixed wood tree pattern had the highest biomass. Thus, cocoa + mixed wood trees is the better ecosystem in producing biomass.

Litter biomass and necromass

Biomass on the forest floor is acquired from coarse (intact) and fine (partially deomposed) litter, and the remains of dead plants, called necromass. The the biomass of coarse litter, fine litter, and necromass are presented in Table 3. The biomass potential of litter and necromass was significantly different among patterns of farming. Within above-ground and below-ground biomass, value of litter biomass and necromass vary widely, but the cocoa + mixed wood trees pattern has the highest biomass of all farming patterns. This again shows that cocoa + mixed wood tree farming patterns are the better ecosystem in producing biomass.

Litter production

Litterfall is a growing mass of vegetative and reproductive organic material caused by aging factors (senescence) from stress by mechanical factors (as example the wind) or combination of both, and through death or destruction of the whole plant by extreme weather (rain and wind) (Brown, 1984). We estimated litterfall production per year from observations during 6 months in various agro-ecosystem types (Table 4). Total litterfall and its components from various farming pattern varied widely, but the cocoa + mixed wood tree farming pattern has the highest total litterfall and its components of all farming patterns.

It shows that cocoa farming patterns + mix wood tree was the better ecosystem in producing total litterfall and its components (leaves, wood/stalk/branches and reproductive organs) as biomass. Cocoa farming patterns + mixed wood tree was the best cocoa farming pattern at the margin areas of LLNP, suggesting that the LLNP Indonesia could be sustainable and serve as a place of research, without giving up the cocoa farming.

Litter decomposition rate

The litter decomposition process is an essential part in the dynamics of nutrients in an ecosystem and thus it provides useful clues about the condition of the ecosystem in relation to the cycles and availability of nutrients in the soil (Berg and McClaugherty, 2008). Benefits of litter decomposition for soil fertility and crop heavily depend on the production and decomposition rates (Mindawati, 1999). The chemical composition of litter also determines the number of nutrients that are returned to the soil to create a good substrate for decomposing organisms. Results of litter weight loss measures and average decomposition rates are shown on Table 5.

The highest dry weight loss was achieved by the cocoa + candlenut farming pattern, which differed significantly from all other farming patterns, except monoculture cocoa. This suggests that cocoa + candlenut and monoculture cocoa farming patterns have litter that decomposes faster. When compared with the cocoa + mixed wood trees, the dry weight loss of the litter in cocoa + candlenut was 5.7% higher. The low loss of weight on cocoa + mixed wood trees shows that litter produced by this farming pattern was more resistant to decomposition. According to Sulistiyanto et al. (2005) most material that is soluble in litter has a simple organic structure, including glucose, phenolic and amino acids, while the poorly soluble fractions (lignocellulose) are typically composed of lignin, cellulose and xylan.

The weathering constant value (k) is commonly used to compare the rate of decomposition between plant species or between different environments (Sulistiyanto et al., 2005). The rate of litter decomposition in cocoa + mixed wood tree farming patterns was significantly lower than cocoa + candlenut and monoculture cocoa farming patterns, while the other agro-ecosystem farming patterns did not differ significantly (Table 5). Litter decomposition speed is affected by abiotic factors such as humidity, temperature, light, sea level, type of substrate, type of decomposers and vegetation (Chairul and Yoneda, 2002). Differences in the farming patterns may have led to differences in any of these factors, and certainly did cause differences in vegetation. It seemed that leaf litter in cocoa + candlenut and monoculture cocoa farming patterns had a simpler composition, allowing to more and easy decomposition. Differences in patterns of farming also cause differences in the environmental temperature. The temperature will affect the physiological properties of microorganisms that live in the environment. Any increase in temperature will increase the rate of metabolism of the organism (Osono and Takeda, 2006), allowing for an easier decomposition of litter. In contrast, cocoa + mixed wood trees, cocoa + fruit trees, and cocoa + teak farming patterns all seem to have a more complex composition and thus slower decomposition rate.

Farming income from different agro-ecosystem types

Result recapitulation of the income analysis on a various farming patterns that managed by farmers are presented on Table 6. The average income of different farming patterns were significantly different (Table 6). Cocoa + candlenut gave the highest average revenue-per-year of IDR16, 348,000/ha/year. But this did not differ significantly from the average income for farmers using the cocoa + mixed wood trees (IDR16,300,200) or cocoa + fruit tree farming patterns. The cocoa crop is a mainstay commodity for the local community due to its high productivity and the price stability of cocoa beans (Effendy, 2015).

The resource deployment and capital of farmers rests on the cocoa crop and additions. Cocoa + mixed wood trees, cocoa + fruit trees, cocoa + candlenut, and cocoa + teak all provide a double benefit. Farmers earn money from both the cacao crop and from the result of the crop inserts (candlenut, wood and fruit) to obtain a higher income.

Materials and Methods

Study site

The research was conducted in the Sigi Regency of Central Sulawesi, Indonesia (Fig. 3). This location was selected because it is located in the buffer zone area of LLNP. Many residents in this area have converted forest land into cocoa farms using different cropping patterns. Cocoa farm cropping patterns in the buffer zone of LLNP include: cocoa farming + mixed wood tree (agroforestry complex), cocoa farming + fruit trees (agroforestry simple), cocoa farming + candlenut trees (agroforestry simple), cocoa farming + teak trees (agroforestry simple), and monoculture cocoa farming.

Research was conducted from January to December 2015, at a site 700-850 m above the sea level. Data collected for each land type were: (1) Species composition and density of vegetation; (2) Biomass production, litterfall, and rate of decomposition; and (3) Farmers' incomes. Comparison of species composition and density of vegetation was done by categorizing sites based on four land types: (1) natural forest (NA), the primary forest found in LLNP without farm crops, (2) agroforestry complex (AFC), a cocoa plantation owned by a farmer that also included different types of plants and trees, (3) agroforestry simple (AFS), a plantation owned by a farmer that had one of: cocoa + fruit trees, cocoa + candlenut, or cocoa + teak, and (4) monoculture cocoa (MC), a plantation owned by a farmer that contained only cocoa. For each land type, 3 replicate plots were used; replicate plots were located in different areas with consideration of environmental factors, especially the condition of the slope/land, in a randomized block design, in which the grouping as replication based on the degree of the slope: 0-15%, 15-30% and >30%.

Field sampling and measurements

Plot determination was done using the double swath method of (Indriyanto, 2006). For each land type, in the area designated as the study location, plots of 100 x 100 m were marked out. This large plot was then divided into 25 subplots of 20 x 20 m. Each subplot was censused for trees (diameter at breast height (dbh) > 20 cm). The further subplot was divided into three sizes: a 10 x 10 m area where poles (dbh 10-20 cm) were sampled, a 5 x 5 m area used to samplings (dbh < 10 cm and height > 1.5 m), and a 2 x 2 m area that in which seedlings and low plants were censused (Fig. 4).

Species composition, biomass and decomposition rates and farmers income samples for each type of land were selected intentionally (purposive sampling) to allow consideration of the effect of slope (as was done for species' composition and density data), and to keep the age of the cacao crop, teak, and pecan trees homogeneous across land types. Biomass potential was estimated using allometric equations (Inoue et al., 2004; Hairiah and Rahayu, 2007; Smiley and Kroschel, 2008; Komiyama et al., 2002; Ebuy et al., 2011; Tinker et al., 2010; Komiyama et al., 2005). Biomass estimation for cocoa crops used equations from Smiley and Kroschel (2008) in the same area:

$$Y = 0.202\ D^{2.112} \quad (1)$$

Where, D = cocoa trunk diameter at a height of 50 cm below the first branching (*jorquete*).

Biomass calculation of woody and branching necromass used the same allometric formula for live trees, while for fall down trees that were not branched and/or branched the biomass was calculated based on the volume of the cylinder Hairiah and Rahayu (2007):

$$BK\ (kg/necromass) = \pi\rho HD^2/40 \quad (2)$$

Where, ρ = density of wood (g.cm-3), H = height/length of necromass (cm), D = diameter of necromass (cm).

Root biomass was estimated as the ratio of the canopy root 4:1 for tree on dry land (Hairiah and Rahayu, 2007). Seedling plant roots and lower level plant roots were sampled using a root trenching method (Wardah, 2008). All samples of biomass were dried in the oven for 48 h at a temperature of 80 °C before weighing (Suprayogo et al., 2004).

Litter production was measured by collecting litter that fell on the forest floor using litter traps 100 x 100 x 20 cm placed randomly on the forest floor. 4 to 5 litter traps were used for each land type use. Litter was collected every month (30 days) for 6 months, and then separated into its components (leaves, stems/branches/twigs, and reproductive organs, namely, flowers and fruits and seeds). After collection, all litter was dried in an oven for 48 h at a temperature of 80 °C, weighed (Rosleine et al., 2006).

Litter decomposition levels were estimated using six litter bags made of nylon (20 x 20 cm2) with a mesh size of 2.0 mm placed in each land type. Each bag was filled with approximately 50 g fresh leaf litter and then placed on the forest floor (Rosleine et al., 2006). Litter bag content was collected after one month for six months and then dried in the oven. Decomposition rates were calculated using an exponential regression equation, based on the litter weight loss that remained in a bag, the formula exponential model:

$$N_t/N_0 = e^{-kt} \quad (3)$$

Where, N_0 = weight of litter at start of the trial, N_t = weight of litter at the time *t* (end of the trial), *e* = mathematical constant (~2.72), *k* = coefficient of decomposition, and *t* = time (days, weeks or months).

To estimate income from farming, data were collected from 10 farmers of each cocoa farming pattern. Five cocoa farming patterns were identified, namely:

A = cocoa farming + mix wood tree (agroforestry complex);
B = cocoa farming + fruit trees (Agroforestry simple);
C = cocoa farming + candlenut trees (Agroforestry simple);
D = cocoa farming + teak trees (Agroforestry simple); and
E = monoculture cocoa farming.

On each farm, up to five sample plots were used for sampling. The plots were 20 x 20 m (trees of dbh >20 cm); 10 x 10 m (dbh = 10-20 cm); and 2 x 2 m (dbh <10 cm). Income cocoa farming patterns calculated using the formula:

$$\pi = \Sigma\ (TR - TVC)\ \text{ if,}$$

$$TR = p_i{*}Q_i \text{ and } TVC = w_i{*}X_i$$

$$\pi =$$

Where,

π = income
Q_i = outputs
p_i = output prices
x_i = inputs
w_i = input prices

Conclusion

The results showed that using a pattern of cocoa + mixed wood trees (agroforestry complex) produced the highest biomass. The pattern of cocoa + candlenut has given the highest average income per year, but the pattern of cocoa + mixed wood trees did differ significantly from that using candlenut. The highest dry weight loss was achieved by the cocoa + candlenut farming pattern, which differed significantly from all other farming patterns, except monoculture cocoa. This suggests that cocoa + candlenut and monoculture cocoa farming patterns have litter that decomposes faster. When compared with the cocoa + mixed wood trees, the dry weight loss of the litter in cocoa + candlenut was higher. The low loss of weight on cocoa + mixed wood trees shows that litter produced by this farming pattern was more resistant to decomposition. It is suggested that cocoa farming with mixed wood trees (agroforestry complex) along the perimeter of the LLNP forest will support the sustainability in biodiversity, water catchment areas and disaster control.

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