Songklanakarin J. Sci. Technol.
43 (2), 414-421, Mar. - Apr. 2021

http://www.sjst.psu.ac.th

Original Article

Diversity of arthropods and decreased seed weight for various cocoa plantation systems

Flora Pasaru[1*], Alam Anshary[1], Mahfudz[1], Shahabuddin Saleh[1], Mohammad Yunus[1], Burhanuddin Nasir[1], and Effendy[2]

[1] *Department of Agrotechnology, Faculty of Agriculture, Tadulako University, Palu, Central Sulawesi, 94118, Indonesia*

[2] *Department of Agriculture Economics, Faculty of Agriculture, Tadulako University, Palu, Central Sulawesi, 94118, Indonesia*

Received: 25 May 2019; Revised: 3 October 2019; Accepted: 25 February 2020

Abstract

Cocoa farmers in Palolo sub-district conducted cocoa cultivation by implementing three cocoa cropping systems, including the cocoa cropping system without using shade trees (A1), using a number of permanent shade trees (A2), and using natural forests as the shade trees (A3). The aim of the study was to determine the diversity of arthropods and decreased seed weight in the three cocoa cultivation systems. The sampling of arthropods used pitfall traps, light trap, and Yellow Fan Trap. The found 2684 arthropod individuals represented 12 orders, 47 families and 106 species. Diversity index and abundance index were the highest for cocoa crop ecosystem A2 (2.9 and 13.1). The largest decrease in weight of cocoa seeds was found in the A1 locations (8.34%) and the lowest in the A3 locations (3.61%). We recommend that cocoa cultivation should use protective trees.

Keywords: cocoa cultivation, diversity of arthropods, seed weight

1. Introduction

One of the main causes of tropical forest loss is their conversion to agricultural cultivation systems (Achard *et al.*, 2002; Margono *et al.*, 2012; Margono, Potapov, Turubanova, Stolle, & Hansen, 2014; Wilcove, Giam, Edwards, Fisher, & Koh, 2013), especially of palm oil, cocoa, and rubber. Because the world demand for chocolate continues to increase (Rice & Greenberg, 2000; Bisseleua, Missoup, & Vidal, 2009), cocoa has become the most important commercial crop in the world. Cocoa is mostly grown by small farmers in Indonesia (Effendy, 2018).

Of the cocoa production in Indonesia, around 65% is produced in Sulawesi (Clough, Faust, & Tscharntke, 2009; Leuschner *et al.*, 2013), where about 50% of the cocoa cultivation area was located on ex-forest land (Rice & Greenberg, 2000). Cocoa has been traditionally cropped in primary or secondary forests (Rice & Greenberg, 2000). In Central Sulawesi (a part of Sulawesi), where the study was conducted, there was a traditional planting system that was changed by removing shading native forest trees and replacing them with shade trees, such as *Gliricidia sepium* (*G. sepium*) or *Cassia sp*., or with trees that provide edible fruits, wood or other valuable products.

In general, young cocoa crops are still cultivated under shade trees, but after adulthood the shade trees are often completely eliminated, because farmers want to increase the yield of cocoa seeds (Belsky & Siebert, 2003; Bisseleua *et al.*, 2009; Rice & Greenberg, 2000; Siebert, 2002; Steffan-Dewenter *et al.*, 2007; Tscharntke *et al.*, 2011). The motivation was to reduce competition for sunlight, water and nutrition between cocoa and shade trees (Belsky & Siebert, 2003; Rice & Greenberg, 2000; Schwendenmann *et al.*, 2010). Changes in cocoa cultivation have had a number of negative consequences, especially loss of biodiversity, increased soil erosion due to reduced protection from heavy rain, and

*Corresponding author
Email address: florapasaru@yahoo.com

reduced carbon storage in biomass (Montagnini & Nair, 2004; Muhardi & Effendy, 2017; Rice & Greenberg, 2000;). In addition, various primary or secondary forest ecosystem services provided by the trees were no longer available to local communities, including wood supply, fuel, and fruit production (Tscharntke *et al.*, 2011). Although recent studies in tropical agroforests have discussed these benefits, little is known about the cocoa cultivation system effects on the diversity of arthropods and the decrease in weight of cocoa seeds.

Arthropoda as one of the important components in the ecosystem could be used as an indicator of the quality of the forest environment and in the agricultural environment. Besides that, arthropods could be used as consideration material for pest management. Arthropods also play a role in reshaping organic matter to maintain soil fertility, thus also maintaining the ongoing nutrient cycle in agricultural agroecosystems (Parzanini, Parrish, Hamel, & Mercier, 2018; Vaes-Petignat & Nentwig, 2014; Watanasit, Chaiyathape, & Permkam, 2002).

The aim of this study was to compare the alternative cocoa cultivation systems with respect to the diversity of arthropods and the decrease in weight of cocoa seeds. In Central Sulawesi, shady and non-shady cocoa cultivation systems occur together, adjacent to each other in the environment, and we compared three widespread cocoa cultivation systems (cocoa without shade trees; the shade of legumes *G. sepium*, *Cassia sp*., trees that provided edible fruits; and natural forest shade).

2. Materials and Methods

2.1 Study site description

This study was conducted in Pangana Sejahtera village, Palolo sub-district, Sigi regency. Sigi regency is located at an altitude of 600 meters above sea level. The study sites were cocoa farms owned by farmers. The selection and determination of location were conducted using a survey method and purposive sampling, namely the regions based on their potential as cocoa production centers. The study sites were divided into three types based on the cocoa cultivation system, namely cocoa crop without shade trees (A1), cocoa crop by using some shade trees species (A2), and cocoa crop using natural forest shade trees (A3) (Figures 1a, 1b, and 1c).

2.2 Sampling of arthropods

Arthropod samples at each study site (Figure 1a, 1b, 1c) were collected from 3 sample plots, and each sample plot had 5 sampling points for pitfall trap, 2 points for yellow fan trap, and 1 point for light trap. Thus each plot required 8 arthropod traps. Each sample plot was determined randomly and the installation of the trap devices was systematic, so that the number of Arthropod traps needed at each study site was 24 (consisting of 15 pitfall traps, 6 yellow fan traps, and 3 light traps).

The pitfall trap was made of plastic beaker (size 200 ml), 15 cm high and 10 cm wide. It was filled with clean water having added detergent and salt to 1/3 level. This was inserted into the ground so that the mouth was level with the ground surface. To protect the trap from rainwater or fallen

a b c

Figure 1. (a) cocoa crop without shade trees (A1)
(b) cocoa crop using several shade trees (A2)
(c) cocoa crop using natural forest shade trees (A3)

leaves and other impurities, a zinc cover of 20 cm was installed on top with wooden supports of 20 cm height. Such trap was placed on each observation plot in each sampling site. It was used to sample the species and populations of active moving arthropods above the ground level in cocoa plantations. For each observation plot, 5 traps were used, with the distance between the traps 10 m, and collection at 1 x 24 hours.

The "Light Trap" tool consisted of a pulling or lure lamp, with part of the lamp in a plastic container (basin), as a place to store insects that came because they were attracted to the light. Insects that are attracted to light would fall into a reservoir containing detergent and salt solution. This tool was installed for 1x24 hours to catch insects that are attracted to light. One piece was put in the middle of the observation site in each observation plot.

Yellow fan trap is made of a yellow plastic container with a diameter of 25 cm, placed on a table (size 30 cm x 30 cm x 1 m), and is placed between crops (installed in an open place to be easily seen by predatory insects) in each observation plot. This tool was used to trap insects that flew and were carried away by the wind. It was filled with a solution of soap and salt water so that insects were trapped, and was used for 1 x 24 hours before collection of accumulated samples.

The sampling of active arthropods on the ground and arthropods that actively flew above the surface using pitfall trap, light trap, and yellow fan trap followed the methods of Price & Sherpard (1980) and Whitcomb (1980).

All catches from the traps at 6 observation times of each site were collected, with the observations conducted every 14 days. Observation of arthropods was conducted in the morning from 07.00 until 10.00 local time (wita). Trapped arthropods were separated by using a tea filter and rinsed with clean water, then they were put in a collection bottle containing 70% alcohol. Each arthropod from each type of trap tool was separated and labeled according to the time of observation and the site, and was taken to the Laboratory of Pest and Plant Disease of the Faculty of Agriculture, Tadulako University, for identification of species, and tallying the numbers of individuals.

2.3 Identification of arthropods based on morphological characteristics

Identification of arthropods was conducted in orders, families, genera. The classification of arthropods was based on taxonomy and trophic structure. Identification could be done with the CPC 2002 program and the key book of determination Borror, Triplehorn, & Johnson, (1992).

Morphological observations were conducted using an electron microscope.

2.4 Arthropoda based on its functional role

The study samples were arthropods trapped in cocoa plantation ecosystems. The variables observed were diversity composition according to the roles in ecology (phytophagus, parasitoid, predator, or decomposer) and we focused more on natural enemies while regarding pollination there are several prior studies, such as Frimpong *et al.* (2009); Frimpong-Anin *et al.* (2014) and Adjaloo and Oduro (2013). Other variables were arthropod composition according to taxonomic groupings (orders, families, and genera), and abundance of arthropods (arthropod diversity and number of arthropod individuals) and arthropod diversity index (H ') and the Simpson index (λ).

2.5 Data analysis

Data analysis was based on diversity values according to Shannon-Wiener (H '), and the Simpson index (Ludwig & Reynold 1988). The diversity indexes that are widely used in ecological studies are the Shannon – Wiener index and the Simpson index.

The Shannon index emphasizes species richness, while the Simpson index emphasizes abundance. The diversity of arthropods was calculated using the formula:

$$H' = -\sum_{i=1}^{s} pi \ln pi$$

where:
H' = Shannon-Weiner diversity index
S = Number of Families
Pi = The proportion of the i^{th} family of the total individuals in the sample

$$\lambda = 1 - \left(\frac{\sum ni(ni-1)}{N(N-1)} \right)$$

where:
λ = Simpson Index
N = Total number of individuals
ni = The number of i^{th} individual
Shannon H's diversity classification used criteria that have been modified by Suana & Haryanto (2007) as follows.

Species Diversity Value (H ')	Diversity Level
H < 1	Very Low
1 < H < 2	Low
2 < H < 3	Moderate
2 < H < 4	High
H > 4	Very high

Comparison of the number of species and individuals in each site used ANOVA with the Tukey test (α = 0.01).

The similarity of the arthropod community was quantified using the Bray-Curtis (BC) formula.

$$BC = \frac{\sum_{1=1`} |n_{1i} - n_{2i}|}{\sum_{i=1} (n_{1i} + n_{2i})}$$

where n_{1i} and n_{2i} are the numbers of the ith species in the two samples A and B, respectively.

The percentage decrease in the weight of cocoa seeds was calculated using the equations in Pedigo & Buntin (2003) as follows:

$$P = \frac{U.Nd - D.Nu}{U.(Nd + Nu)}.100\%$$

where:
P = percentage of weight loss of cocoa seeds (%)
U = weight of undamaged cocoa seeds (g)
D = weight of damaged cocoa seeds (g)
Nu = number of undamaged cocoa seeds (fruit)
Nd = number of damaged cocoa seeds (fruit)

3. Results and Discussion

3.1 Diversity of arthropods

Based on the results of observations on the 3 (three) study sites, namely cocoa crop without shade trees (A1), cocoa crop by using some shade trees species (A2), or cocoa crop using natural forest shade trees (A3), the differences in the numbers of families, genera, number of individuals, and Relative Abundance (RA) can be seen in Table 1.

The total number of arthropod species collected in the three study sites was 106 species, representing 12 orders and 47 families. However, there were differences in the number of species by study site. The site A1 had the lowest number of species (27 species) while the highest was for A2 (42 dominant species found). Differences in the number of species at A1 and A2 sites were thought to be related to the plant species diversity, plant structural diversity, percentage of shading, and thickness of litter. The complexity of the community could increase, not because the number of species increased, but because of the increased structural complexity. If in a community both of these elements increased, then the ecological niche available to insects also got larger (Parzanini *et al.*, 2018).

The lowest number of species in the A1 site was also thought to have something to do with the reduced diversity of crop species, so that insects could migrate to habitats that had a more varied species diversity. Of all the species found the ant *O. smaragdina* species *D. thoracicus* was the dominant species in the three study sites, followed by *Irydomirmex sp*., *Helopelthis sp*., *Conopomorpha cramerella*, and spider *Pardosa sp*. This was thought to be related to the behavior of ants, which could spread widely to all habitats and were the most successful of all groups of insects. Although there was a decrease in the diversity of shade trees, this did not have a negative effect on ants, as in the cocoa crop not using shade trees (A1) there were still more ant individuals than other insects.

According to Merjin (2006), the decrease of shade trees did not have a negative effect on ants and beetles in cocoa trees, but the thinning of the shade canopy was related to a decrease in the species richness of ants in cocoa trees. According to Hosang (2003), the group of ant insect arthropods is the dominant insect in the cocoa crop.

The results of this study also show that the diversity of ants remained high in cocoa farms that used several species of shade trees (A2), and had similarities to using natural

Table 1. Diversity of Arthropods found in the study sites (A1, A2, and A3)

No	Family	Genera	Functional roles	Sites			Number	RA
				A1	A2	A3		
1	2	3	4	5	6	7	8	9
1	Formicidae	Oecophylla	(Pr)	133	132	258	523	21.6
2	Formicidae	Dolichoderus	(Pr)	102	104	183	389	16.1
3	Formicidae	Iridomyrimex	(Pr)	0	154	105	259	10.7
4	Lycosidae	Pardosa	(Pr)	33	73	60	166	6.9
5	Gracillaridae	Conopomorpha	(Pt)	63	45	47	155	6.4
6	Araneidae	Gastercantha	(Pr)	23	45	22	90	3.7
7	Pseudococcidae	Planococcus	(Pt)	19	64	0	83	3.4
8	Tetragnathidae	Leucauge	(Pr)	14	45	20	79	3.3
9	Formicidae	Pheidole	(Pr)	0	65	0	65	2.7
10	Lampyridae	Pteroptyx	(Pr)	15	27	11	53	2.2
11	Acrididae	Locusta	(Pt)	0	31	19	50	2.1
12	Scarabaidae	Apogonia	(Pt)	9	9	17	35	1.4
13	Araneidae	Argiope	(Pr)	22	0	13	35	1.4
14	Carabidae	Calosoma	(Dc)	4	10	21	35	1.4
15	Coccinellidae	Menochilus	(Pr)	0	18	11	29	1.2
16	Noctuidae	Spodoptera	(Pt)	4	6	11	21	0.9
17	Aphididae	Toxoptera	(Pt)	21	0	0	21	0.9
18	Coreidae	Mictis	(Pr)	17	0	3	20	0.8
19	Geometridae	Chrysodeixis	(Pt)	8	6	4	18	0.7
20	Termitidae	Macrotermes	(Pt)	0	0	17	17	0.7
21	Isotomidae	Tetracantella	(Dc)	0	6	11	17	0.7
22	Salticidae	Ligurra	(Pr)	0	16	0	16	0.7
23	Asilidae	Choerades	(Pr)	0	10	3	13	0.5
24	Dolichopodidae	Dolichopus	(Pr)	3	7	3	13	0.5
25	Eulopidae	Elasmus	(Pd)	0	13	0	13	0.5
26	Chrysomelidae	Aulacophora	(Pt)	0	4	8	12	0.5
27	Reduviidae	Rhiginia	(Pr)	0	12	0	12	0.5
28	Forficulidae	Forticula	(Pr)	0	11	0	11	0.5
29	Cerambryidae	Stenandra	(Pt)	5	0	5	10	0.4
30	Entomobryidae	Coecobrya	(Dc)	0	9	0	9	0.4
31	Oxypidae	Oxyopes	(Pr)	0	0	9	9	0.4
32	Syrphidae	Asarcina	(Pr)	0	8	0	8	0.3
33	Pieridae	Catopsilia	(Pt)	0	8	0	8	0.3
34	Grylloltalpidae	Gryllotalpa	(Pt)	3	0	5	8	0.3
35	Vespidae	Polistes	(Pr)	2	4	2	8	0.3
36	Pyrhocoridae	Pyrrhocoris	(Pr)	0	8	0	8	0.3
37	Miridae	Helopeltis	(Pt)	117	72	54	243	9.1
38	Elatiridae	Ctenicera	(Pr)	0	7	0	7	0.3
39	Delpacidae	Diceroprocta	(Pr)	0	2	5	7	0.3
40	Scolytidae	Scolytus	(Pt)	7	0	0	7	0.3
41	Tipulidae	Ablautus	(Pt)	3	0	3	6	0.2
42	Gryllidae	Gryllus	(Pt)	6	0	0	6	0.2
43	Staphylinidae	Paederus	(Pr)	0	6	0	6	0.2
44	Tenebreonidae	Alphitobius	(Pt)	5	0	0	5	0.2
45	Coccinellidae	Cyceloneda	(Pr)	0	5	0	5	0.2
46	Mantidae	Mantis	(Pr)	0	3	2	5	0.2
47	Japygidae	Metjapyx	(Pr)	0	0	5	5	0.2
48	Saturnidae	Attacus	(Pt)	0	0	4	4	0.2
49	Hesperidae	Erionata thrax	(Pt)	0	4	0	4	0.2
50	Evaniidae	Evania	(Pd)	0	0	4	4	0.2
51	Sphingidae	Herse	(Pt)	0	0	4	4	0.2
52	Tettigonidae	Microcentrum	(Pr)	0	0	4	4	0.2
53	Apididae	Apis	(Pt)	0	0	3	3	0.1
54	Brachonidae	Chelonus	(Pd)	0	3	0	3	0.1
55	Pentatomidae	Nezara sp.	(Pt)	0	0	3	3	0.1
56	Rhagionidae	Chrysopilus	(Pr)	0	0	2	2	0.1
57	Tachinidae	Exorista	(Pd)	0	2	0	2	0.1
58	Ichnoumoridae	Ichneumon	(Pd)	0	2	0	2	0.1
59	Papilionidae	Papilio	(Pt)	0	0	1	1	0
60	Tepritidae	Bactrocera	(Pt)	4	3	0	7	0.3

Table 1. Continued

No	Family	Genera	Functional roles	Sites			Number	RA
				A1	A2	A3		
1	2	3	4	5	6	7	8	9
61	Arctiidae	Cyana	(Pt)	10	4	0	14	0.5
62	Tephritidae	Dacus	(Pt)	4	3	0	7	0.3
	Number of Individuals			656	1066	962	2684	
	Number of Species			27	42	37	106	

Note: RA = Relative Abundance, Pr = Predator, Pd = Parasitoid, Pt = Phytophagous, Dc = Decomposer

forests as shade (A3). *O. smaragdina* insects and *D. thoracicus* are in the order of Hymenoptera, the family of Formicidae.

According to Walwork (1976), the order of Hymenoptera occupies 80% of the arthropod population. Besides that, it also relates to the availability of food sources, namely the variety of shade trees in the study sites A2 and A3. In addition, it was suspected that *Planoccus spp*. which is found in many cocoa fruits was symbiotic with these two ant species. *Planoccus spp.* insects remove sugar liquid as an alternative food source for *O. smaragdina* and *D. thoracicus*. Food of Oecophylla could consist of insects and sugar liquid. According to Bluthgen & Fiedler (2002), sugar liquid was also obtained by Oecophylla through symbiosis with aphids (Aphididae; Homoptera). These ants are predatory and aggressive and are used as natural biocontrol agents (Mele & Cuc, 2000).

Oecophylla is one of the arboreal ants forming a nest in the canopy section of the tree. The nests are formed by interweaving several young leaves using silk that is released from the mouth of a larva (Holldobler, & Wilson, 1990). This was the success of Oecophylla, so that the number of individuals found was dominant in all three study sites. Likewise the black ants *D. thoracicus* nest in shade on the trees. This ant is an aggressive predator in cocoa crops and repels some pest insects (Bluthgen & Fiedler, 2002).

Irydiomirmex sp. is found in lush and shade plants and is a predator to Cocoa Fruit Borer (CFB) larvae. For *Helopeltis spp*. insect and *C. cramerella*, these individuals are more commonly found in humid, shaded, and dirty environments (untreated plants); these species like shade and humidity. The *Helopeltis spp.* insects can live at temperatures of 24-27.5 C with about 75% relative humidity (Kalshoven, 1981).

The composition of arthropods based on their roles can be seen in Figure 2. Cocoa plantations with some shade trees (A2) had more groups of predators, parasitoids, and decomposers than in cocoa crop without shade trees (A1), but the number of phytophagous group in site A1 was the highest, while this was the lowest in cocoa crop using natural forest as shade (A3).

Figure 2 shows that the cocoa crop without using shade trees (A1) had more phytophagous arthropod groups, while the group of predators and decomposers was lesser and there was not even a parasitoid group found that was related to habitat existence. One of the drivers of increasing crop pest organisms is the continuous and consistent availability of food

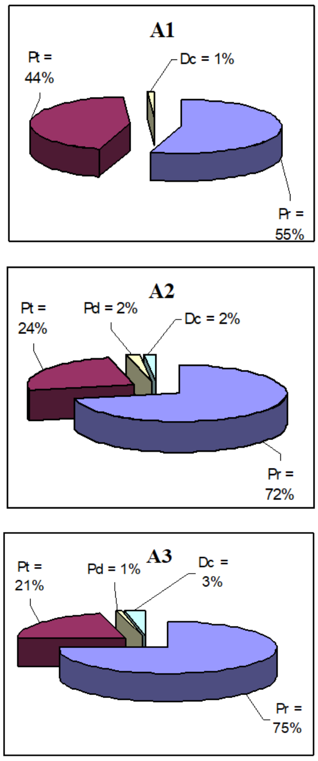

Figure 2. Percentages of arthropods by functional roles
Note: Pr = Predator, Pd = Parasitoid, Pt = Phytophagous, Dc = Decomposer

(Altieri, 1999). According to Tobing (2009), environmental simplification has an impact on biodiversity in terms of low habitat values, and loss of various useful insects due to the loss of wild plants and flowering plants as food sources.

The results of the estimation of the species numbers for each study site indicated that the number of species collected was close to the number of species that could be found in these three sites. The accumulated species curve (Figure 3) shows that the highest number of species in the three study sites occurred on week 3, namely 30 animals (A1 site), 42 animals (A2 site) and 37 animals (A3 site). In the following week, no additional species were found.

Figure 4 shows that the highest diversity of arthropod species was obtained in cocoa crops that used several types of fixed shade trees (A2), indicating that more

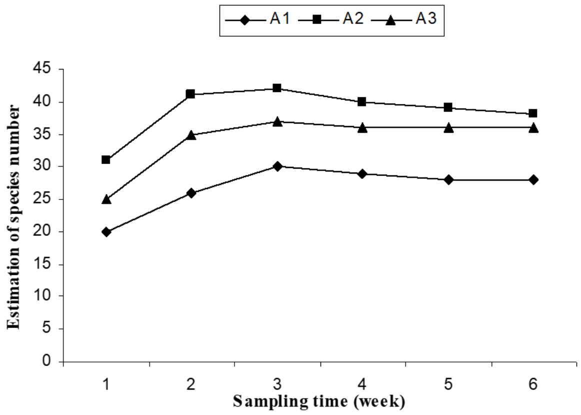

Figure 3. Time traces of arthropod sample counts

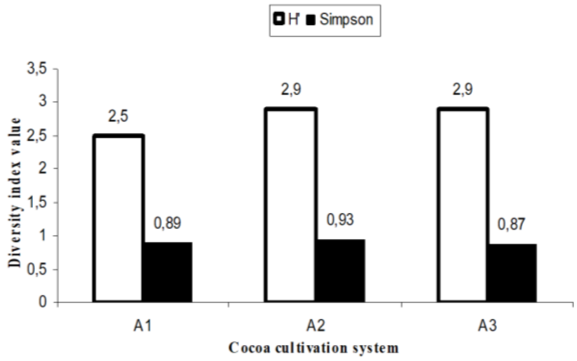

Figure 4. The diversity indexes of arthropods

arthropods were attracted to cocoa crops that used shade trees than to cocoa crops that did not use shade trees. There was a correlation between the number of species with the density in farms that used shade trees. In cocoa farms that used shade trees, the cocoa ecosystem was relatively more stable than in cocoa crops that did not use shade trees, so the highest diversity index was obtained at A2 (2.9) and the Simpson diversity index (0.93) was higher than for cocoa crops without using shade trees.

Similarity analysis of arthropod communities showed that arthropod communities in the three study sites were quite similar to each other (55% to 61%). Nevertheless, arthropod communities in A2 and A3 sites were more similar to each other than to A1 (Table 2).

The similarity of arthropod communities in sites of A2 and A3 was thought to occur because of the similarity of habitat conditions: both had shade trees, both had complete components of the food chain, except in the study site A2 the number of each species was higher and varying, so it was thought to play a role in ecosystem stability. The existence of various shade trees influenced the diversity of the presence of arthropods in the cocoa cropping system, and could create microclimates that were somewhat similar in temperature and humidity. The stability of the insect community depends not only on diversity but also on the density level in tropics naturally (Southwood & Way, 1970).

3.2 Decrease in weight of cocoa seeds

The percentage decrease in weight of cocoa seeds by the various cocoa cultivation systems is shown in Table 3. Table 3 shows that the cocoa crop with natural forest shade had the least decrease in weight of cocoa seeds over 3 months of observation, namely with an average range from 1.99 to 6.42% per tree observed. Cocoa plants without shade have the largest decrease in weight of cocoa seeds over 3 months of observation, namely with an average range from 7.64 to 8.75% per tree observed. This was related to their habitat, as cocoa plantations with natural forest shade (A3) had more predators, parasitoids and decomposers than cocoa crop without using shade trees (A1). Many predators, such as Irydiomirmex sp. control cocoa pod borer larvae (CPB) so that the weight loss of seeds would be low.

Table 2. The Bray-Curtis similarity indexes for arthropods in three study sites

		Site of the Cocoa Cropping System		
		A1	A2	A3
Study Site	A1	1		
	A2	0.55	1	
	A3	0.58	0.61	1

Table 3. Decrease in weight of cocoa seeds

Treatment (cocoa cultivation system)	Repeat	Decrease in Weight of Dry Seeds (%)						Average
		i^th Observation						
		1	2	3	4	5	6	
Without shade	I	11,79	10,75	10,06	11,03	5,05	3,83	8,75
	II	12,54	8,54	15,64	6,32	5,67	3,02	8,62
	III	19,31	14,51	3,31	0,00	8,72	0,00	7,64
	Average	14,55	11,27	9,67	5,79	6,48	2,28	8,34[a]
Some Types of Shade	I	14,97	6,03	6,40	6,80	10,97	10,04	9,20
	II	10,20	5,72	6,30	6,29	16,72	7,40	8,77
	III	16,18	6,52	4,10	1,85	8,00	2,50	6,52
	Average	13,78	6,09	5,60	4,98	11,90	6,64	8,17[a]
Natural Forest Shade	I	0,06	2,02	1,75	2,95	1,72	3,43	1,99
	II	4,58	3,01	0,70	1,30	1,51	3,42	2,42
	III	9,80	6,57	4,85	1,70	10,57	5,05	6,42
	Average	4,82	3,87	2,43	1,98	4,60	3,97	3,61[b*]

Note: The same letter indicates no significant difference, * significantly different at α = 5%

The results from statistical analysis show that the F count = 7.690 with a probability of 0.022 < 0.05, indicating rejection of hypothesis H0, meaning that there was a difference in the weight decreases of cocoa seeds by cocoa cultivation systems over 3 months of observation. The results from Tukey test show that the decrease in weight of cocoa seeds in cocoa crops with natural forest shade was significantly different from cocoa without shade or cocoa which used some types of shade, at the α level of 5% in a two-tailed test. Cocoa that used some types of shade was not significantly different from cocoa without shade. The highest decrease in weight of cocoa seeds occurred in cocoa without shade (8.34%) and the lowest was for cocoa using natural forest shade (3.61%). This shows that the cocoa trees really needed a protective tree in their growth.

4. Conclusions

The cocoa cultivation system using some fixed shade trees (A2) had the highest diversity of Arthropods, followed by cocoa crops using natural forests as shade trees (A3), and the lowest diversity was found in cocoa crops without using shade trees (A1). Numbers of species found were 42 for A2, 37 for A3, and 27 for A1. Diversity indexes (H') of A2 and A3 were equal at 2.9 and A1 had 2.5. Regarding composition of arthropods based on their functional roles, the most predator arthropods were found in A2 (28.69%) followed by A3 (27.38%), and the least were in A1 (13.82%). The highest number of phytophagous ones was found in A1 (10.62%) and the lowest number in A3 (7.71%), while A2 had 9.13%. No parasitoids were obtained in A1 (0), while some were in A2 (0.75%), and in A3 (0.60%). For decomposers the lowest number of individuals was in A1 (0.15%), with A2 (0.56%) and A3 (0.60%) having more of them. The highest decrease in weight of cocoa seeds was found in the cocoa cultivation system without shade (8.34%) and the least was in the cocoa cultivation system using natural forest shade trees (3.61%).

Acknowledgements

We would like to thank the Ministry of Research, Technology and Higher Education of the Republic of Indonesia for funding this research.

References

Achard, F., Eva, H. D., Stibig, H. J., Mayaux, P., Gallego, J., Richards, T., & Malingreau, J-P. (2002). Determination of deforestation rates of the world’s humid tropical forests. *Science*, *297*(5583), 999–1002. *doi:*10.1023/A:1005956528316

Adjaloo, M. K., & Oduro, W. (2013). Insect assemblage and the pollination system of cocoa (*Theobroma cacao* L). *Journal of Applied Biosciences*, *62*, 4582 – 4594.

Altieri, M. A. (1999). The ecological role of biodiversity in agroecosystems. *Agriculture, Ecosystems and Environment*, *74*(1-3), 19-31.

Belsky, J., & Siebert, S. (2003). Cultivating cacao: Implications of sun-grown cacao on local food security and environmental sustainability. *Agriculture and Human Values*, *20*(3), 277–285.

Bisseleua, D., Missoup, A., & Vidal, S. (2009). Biodiversity conservation, ecosystem functioning, and economic incentives under cocoa agroforestry intensification. *Conservation Biology*, *23*(5), 1176–84. *doi:* 10.1111/j.1523-1739.2009.01220.xPMID:19765036

Bluthgen, N., & Fiedler, K. (2002). Interactions between weaver ants Oecophylla smaragdina, homopterans, tress and linnas in an Australian rain forest canopy. *Journal of Animal Ecology*, *71*, 793-801.

Borror, D. J., Triplehorn, C. A., & Johnson, N. F. (1992). *Pengenalan Pelajaran Serangga*. (6^{th} ed.). Diterjemahkan dan disunting oleh S. Partosoedjono dan M. D. Brotowidjoyo. Yogyakarta, Indonesia: Gadjah Madaq University Press.

Clough, Y., Faust, H., & Tscharntke, T. (2009). Cacao boom and bust: sustainability of agroforests and opportunities for biodiversity conservation. *Conservation Letters*, *2*(5), 197–205.

Effendy. (2018). Changes of technical efficiency and total factor productivity of cocoa farming in Indonesia. *Bulgarian Journal of Agricultural Science, 24*(4), 566-573

Frimpong-Anin, K., Adjaloo, M. K., Kwapong, P. K., & Oduro, W. (2014). Structure and stability of cocoa flowers and their response to pollination. *Journal of Botany*, *2014*, Article ID 513623, 6 pages. doi:10.1155/2014/513623

Frimpong, E. A., Gordon, I., Kwapong, P. K., & Gemmill-Herren, B. (2009). Dynamics of cocoa pollination: tools and applications for surveying and monitoring cocoa pollinators. *International Journal of Tropical Insect Science*, *29*(2), 62–69.

Holldobler, B., & Wilson, E. O. (1990). *The Ants*. Cambridge, MA: The Belknap Press of Harvard University Press.

Hosang, A. L. M. (2003). *Tritrophic interactions between natural enemies, herbivores and cacao in Contral Sulawesi*. Bogor, Indonesia: Graduate School. Bogor Agricultural University.

Kalshoven, M. G., Van der P. A., & P. T. Laan. (1981). *Pests of crops in Indonesia* (edisi terjemahan dan revisi). Jakarta, Indonesia: Ichtiar Baru.

Leuschner, C., Moser, G., Hertel, D., Erasmi, S., Leitner, D., Culmsee, H., … Schwendenmann, L. (2013). Conversion of tropical moist forest into cacao agroforest: consequences for carbon pools and annual C sequestration. *Agroforestry Systems*, *87*(5), 1173–1187.

Ludwig, J. A., & Reynolds, J. F. (1988). *Statistical Ecology*. New York, NY: John Wiley and Sons.

Margono, B. A., Potapov, P. V., Turubanova, S., Stolle, F., & Hansen, M. (2014). *Primary forest cover loss in Indonesia over* 2000–2012. *Nature Climate Change*, *4*(June), 1–6.

Margono, B. A., Turubanova, S., Zhuravleva, I., Potapov, P., Tyukavina, A., & Baccini, A. (2012). Mapping and mon- itoring deforestation and forest degradation in Sumatra (Indonesia) using Landsat time series data sets from 1990 to 2010. *Environmental Research Letters*, *7*(3), 034010.

Mele, P. V,. & Cuc, N. T. T. (2000). *Evolution and Status of Oecophylla smaragdina (*Fabricius) *as a pest control agent in citrus in the Mekong Delta, Vietnam. International Journalof Pestmanagement, 46*(4), 295-301.

Merijn, M. B. (2006). *The contribution of cacao agroforests to the conservation of lower canopy ant and beetle diversity in Indonesia*. Gottingen, Germany: Departement of Crop Science, Agroecology, University of Gottingen.

Muhardi & Effendy. (2017). Cocoa farming patterns for sustainability of Indonesia Lore Lindu National Park (LLNP). *Australian Journal of Crop Science*, *11*(08), 917-924. doi:10.21475/ajcs.17.11.08.pne34

Montagnini, F., & Nair, P. (2004). Carbon sequestration: An underexploited environmental benefit of agroforestry systems. *Agroforestry Systems, 61*(1-3), 281–295.

Parzanini, C., Parrish, C. C., Hamel, J-F., & Mercier, A. (2018). Functional diversity and nutritional content in a deep-sea faunal assemblage through total lipid, lipid class, and fatty acid analyses. *Plos One, 13*(11), e0207395. doi:10.1371/journal.pone.0207395

Pedigo, L. P. & Buntin, G. D. (2003). *Handbook of sampling methods for arthropods in agriculture*. London, England: CRC Press.

Price, J. F., & Shepard, B. M. (1980). Sampling ground predators in soybean fields. In M. Kogan & D. C. Herzog (Eds.). *Sampling Methods in Soybean Entomology*. New York, NY: Springer-Verlag.

Rice, R. A., & Greenberg, R. (2000). Cacao cultivation and the conservation of biological diversity. *Ambio: A Journal of the Human Environment*, *29*(3), 167-173.

Schwendenmann, L., Veldkamp, E., Moser, G., Hölscher, D., Köhler, M., Clough, Y., … Tscharntke, T. (2010). Effects of an experimental drought on the functioning of a cacao agroforestry system, Sulawesi, Indonesia. *Global Change Biology*, *16*(5), 15–30.

Siebert, S. F. (2002). From shade- to sun-grown perennial crops in Sulawesi, Indonesia: Implications for biodiver- sity conservation and soil fertility. *Biodiversity Conservation*, *11*(11), 1889–902.

Southwood, T. R. E. & Way, M. J. (1970). Ecological background to pest management. *Jurnal Concepts of Pest Management*, 7-13.

Steffan-Dewenter, I., Kessler, M., Barkmann, J., Bos, M. M., Buchori, D., Erasmi, S., . . . Tscharntke, T. (2007). Tradeoffs between income, biodiversity, and ecosystem functioning during tropical rainforest conversion and agroforestry intensification. *Proceedings of the National Academy of Sciences of the United States of America*, *104*(12), 4973–4978. *doi:*10.1073/pnas.0608409104

Suana, I. W., & Haryanto, H. (2007). Keanekaragaman Laba-Laba PadaEkosistem Sawah Monokultur dan Polikultur Di Pulau Lombok. *Jurnal Biologi Udayana*, *11*(1), 1-23.

Tobing, C. M. (2009). *Keanekaragaman Hayati dan Pengelolaan Serangga Hama dalam Agroekosistem.* Sumatra, Indonesia: Pidato Pengukuhan Jabatan Guru Besar Tetap. Universitas Sumatera Utara Medan.

Tscharntke, T., Clough, Y., Bhagwat, S. A., Buchori, D., Faust, H., Hertel, D., Wanger, T. J. (2011). Multifunctional shade-tree management in tropical agroforestry landscapes—A review. *Journal of Applied Ecology*, *48*(3), 619–629.

Vaes-Petignat, S., & Nentwig, W. (2014). Environmental and economic impact of alien terrestrial arthropods in Europe. *NeoBiota*, *22*, 23–42. doi:10.3897/neobiota.22.6620

Wallwork, J. A. (1976). *Ecology of soil animals.* London, England: MC Graw Hill.

Watanasit, S., Chaiyathape, K., & Permkam, S. (2002). Effect of some environmental factors on arthropod communities in bat guano. *Songklanakarin Journal of Science and Technology*, *24*(1),15-30

Whitcomb, W. H. (1980). Sampling spiders in soybean fields. In M. Kogan & DAC. Herzog (Eds.) *Sampling Methods in Soybean Entomology*, p. 544-548. New York, NY: Springer-Verlag.

Wilcove, D. S., Giam, X., Edwards, D. P., Fisher, B., & Koh, L. P. (2013). Navjot's nightmare r.evisited: Logging, agriculture, and biodiversity in Southeast Asia. *Trends Ecology Evolution*, *28*(9), 531–540.