BIODIVERSITAS
Volume 20, Number 10, October 2019
Pages: 3075-3085

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d201042

Correlation between some landscape metrics and insect species richness in coffee agroforests in Pangalengan Subdistrict, Bandung District, West Java, Indonesia

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Manuscript received: 21 August 2019. Revision accepted: 30 September 2019.

Abstract. *Withaningsih S, Parikesit, Rabbany MB. 2019. Correlation between some landscape metrics and insect species richness in coffee agroforests in Pangalengan Subdistrict, Bandung District, West Java, Indonesia. Biodiversitas 20: 3075-3085.* The insect community provides valuable ecosystem services and can help maintain ecosystem integrity in human-altered landscapes such as coffee agroforests. The aim of this study was to assess the landscape characteristics of coffee agroforests in the Pangalengan Subdistrict and analyze how those characteristics influence the insect communities. Landscape metric approaches were examined to quantify landscape characteristics and the results analyzed using correspondence analysis to determine variation among samples, and simple linear regression testing was used to determine the influence of those landscape characteristics on the insect community. Seventeen sample locations varied in characteristics based on the proportion of the land cover classes, and landscape characteristics determined the number of insect species. The number of insect species showed strong negative correlation with landscape heterogeneity (R^2=0.456) and number of patches (R^2=0.514) and a weak positive response to the proportion of natural forest remaining (R^2=0.150). Number of insect species showed a strong negative correlation to landscape heterogeneity, number of patches, and number of natural forest remaining simultaneously (R^2=0.514).

Keywords: Coffee agroforestry, insect community, landscape characteristics, Pangalengan

INTRODUCTION

Human activity is a primary cause of landscape change, especially in areas naturally dominated by forests (Luppi et al. 2018). As much as70% of the world's forest lands are located within one kilometer of human-built areas (Dodonov et al. 2016) Landscape changes due to human activities do not always have a negative impact on the ecosystem; for example, many species of insects and invertebrates benefit from the diversification of natural habitats that form many open areas in the landscape. These types of insects benefit from the presence of new landscape patterns because they have the ability to adapt quickly to habitat changes (Dodonov et al. 2016)

Coffee-based agroforestry is an element in the human-built landscape with a role in maintaining ecosystem integrity by supporting ecological processes within it, including carbon storage and biodiversity conservation. The average amount of carbon storage in a coffee agroforest is 41 mg/ha/yr while in a mono-cultural coffee agroforest it is 12.5 mg/ha/year (Hairiah et al. 2010).

Coffee is an important commodity of plantations, especially as a national export commodity, so production needs to be maintained. The total export volume of various Indonesian coffee products in 2014 was 384.82 thousand tons, with an export value of 1.04 billion US dollars (Directorate General of Plantation 2015). Coffee-based plantations also play an important role in supporting the economy as a large contribution from plantation production (approximately 80-95% of the coffee-growing area in Indonesia) is needed to meet the annual coffee export quota (Hairiah and Rahayu 2010).

One of the coffee-producing regions in Indonesia is the Pangalengan Subdistrict, the largest coffee production center in West Java. The Pangalengan Subdistrict has a coffee plant development area of 1,028.10 ha, of which 912.10 ha (88.7%) is cultivated by the community (people's plantations) and 296 ha is cultivated by the private sector (major private plantations). Arabica coffee is the main commodity grown by coffee farmers in the Pangalengan Subdistrict and has been successfully marketed to Japan and elsewhere (Karyani et al. 2018; Djuwendah et al. 2018).

Wildlife plays an important role in the regulation and dynamics of ecosystem services, and insects specifically provide, among others, pollination, biological control, and organic matter decomposition (Noriega et al. 2018). The presence of pollinating insects is the key factor in the success of coffee production because coffee plant flowers require pollination to become coffee plant (Bravo-Monroy et al. 2015). The pollination success of Arabica coffee greatly influences the quality of the coffee beans produced: coffee fruit pollinated with the help of insect pollinators weigh approximately 7% more than without, and the number of fruits per flower set increases by 49% (Roubik 2002; Klein et al. 2003; Karanja et al. 2013).

The spread of insects on coffee plantations is influenced by the landscape characteristics of these plantations and is related to support of insect habitat (Saturni et al. 2016). Measuring landscape metrics is an approach in determining landscape characteristics using algorithms that specifically quantify classes, patches, or entire landscape mosaics (Wu et al. 2007). Among the quantitative landscape metric variables is the diversity of the landscape, demonstrated by the plurality of the components that make up the landscape. Landscape metrics are analyzed by statistical approaches of various types of implementations based on the results of landscape elements visualization (Niesterowicz and Stepinski 2016).

Visualization of landscape elements can be accomplished by several methods including remote sensing, which has the advantage of obtaining a wide range of information using a simpler methodology, making it especially appropriate for conducting habitat analysis (Horning et al. 2016). Furthermore, evaluations of structural pattern and ecosystem function based on ecological data taken at different spatial and temporal scales can be efficiently stored and analyzed using geographic information systems (GIS) (Haines-Young et al. 1993). This study aimed to use remote sensing to determine differences in habitat characteristics of Indonesian coffee agroforestry plantations and how these differences correlate to insect diversity.

MATERIALS AND METHODS

The study was conducted on land adjacent to coffee agroforestry plantations, on community forest management (*Pengelolaan Hutan Bersama Masyarakat* or PHBM) land owned by Perhutani KPH South Bandung, Pangalengan Subdistrict, Bandung District, West Java Province, Indonesia jointly operated with surrounding coffee cropper communities. Insect community data were collected and their coordinates determined by processing satellite image data at the sample location using GIS-based computer software.

Land cover types surrounding coffee agroforestry land were divided into ten types based on Google satellite images and direct observations in the study site: natural forests, plantation forests, pine forests, mixed gardens, tea plantations, vegetable gardens, open fields, bodies of water, roads, and settlements. Insects were collected using the netting method, pan traps, and malaise traps from 90 sample points from the entire population of coffee farmers that were randomly selected using the sampling methods of Lynch et al. (1972). From these 90 sample points, a circle of 500 m radius was established as the area for structural analysis at the micro landscape level (Warren et al. 2005). The sample points for the macro landscape analysis were determined by using each of the 90 insect sampling points as the center point of a block circle and selecting intersected points within a radius of 500 m; this created 17 points that did not intersect which were used as a sample for the landscape analysis. The illustration of sample points determination of the landscape analysis is described in Figure 1, while the distributions of sample points are mapped in Figure 2. A total of 17 sample points on coffee agroforestry land, located in nine villages in Pangalengan Subdistrict, were analyzed as shown in Table 1. The identification of insects was done by research team at the Entomology Laboratory, Museum Zoologicum Bogoriense, Research Center for Biology, Indonesian Institute of Sciences, Bogor, Indonesia.

The landscape matrices of the spatial data were analyzed using Fragstats ver 2.0 (Mc Garigal and Marks 1994). Analysis was performed on measurements of the following landscape parameters: number of patches (NP), large patch index (LPI), and Shannon diversity index (SHDI). Data analysis was conducted using simple linear regression analysis based on the Pearson correlation test with two variables: the characteristics of the coffee plantation landscape and the number of insect species at the sampling locations, while variations in landscape characteristics were determined by correspondence analysis.

Table 1. Location of study sample points in Pangalengan Subdistrict, Bandung District, Indonesia

No.	Sample code	KTH	Village	Coordinate
1	S01	Tegallega	Lamajang	7° 7'41.73"S, 107°31'21.50"E
2	S02	Pancen Alam	Lamajang	7° 8'13.98"S, 107°32'21.87"E
3	S03	Raksawana	Lamajang	7° 8'47.34"S, 107°32'58.11"E
4	S04	Talangsari	Tribaktimulya	7° 8'36.60"S, 107°33'56.17"E
5	S05	Pasir Awi	Tribaktimulya	7° 8'48.65"S, 107°34'59.56"E
6	S06	Margamulya	Margamulya	7° 9'33.17"S, 107°33'35.92"E
7	S07	Batas	Pulosari	7° 9'55.95"S, 107°30'49.99"E
8	S08	Kubangsari 1	Pulosari	7°10'8.77"S, 107°32'14.99"E
9	S09	Rahongsari	Pulosari	7°10'52.93"S, 107°32'45.64"E
10	S10	Kubangsari 2	Pulosari	7°10'1.20"S, 107°33'0.38"E
11	S11	Petak 37	Pulosari	7°10'33.61"S, 107°33'41.99"E
12	S12	Margamukti	Margamukti	7°10'5.05"S, 107°36'38.65"E
13	S13	Warnasari	Warnasari	7°11'52.84"S, 107°30'52.80"E
14	S14	Margaluyu	Margaluyu	7°14'28.47"S, 107°33'16.42"E
15	S15	Batubelah	Pulosari	7°10'20.49"S, 107°31'13.10"E
16	S16	Palimajaya	Sukaluyu	7°12'30.10"S, 107°30'54.34"E
17	S17	Wanasuka	Wanasuka	7°16'31.38"S, 107°36'59.73"E

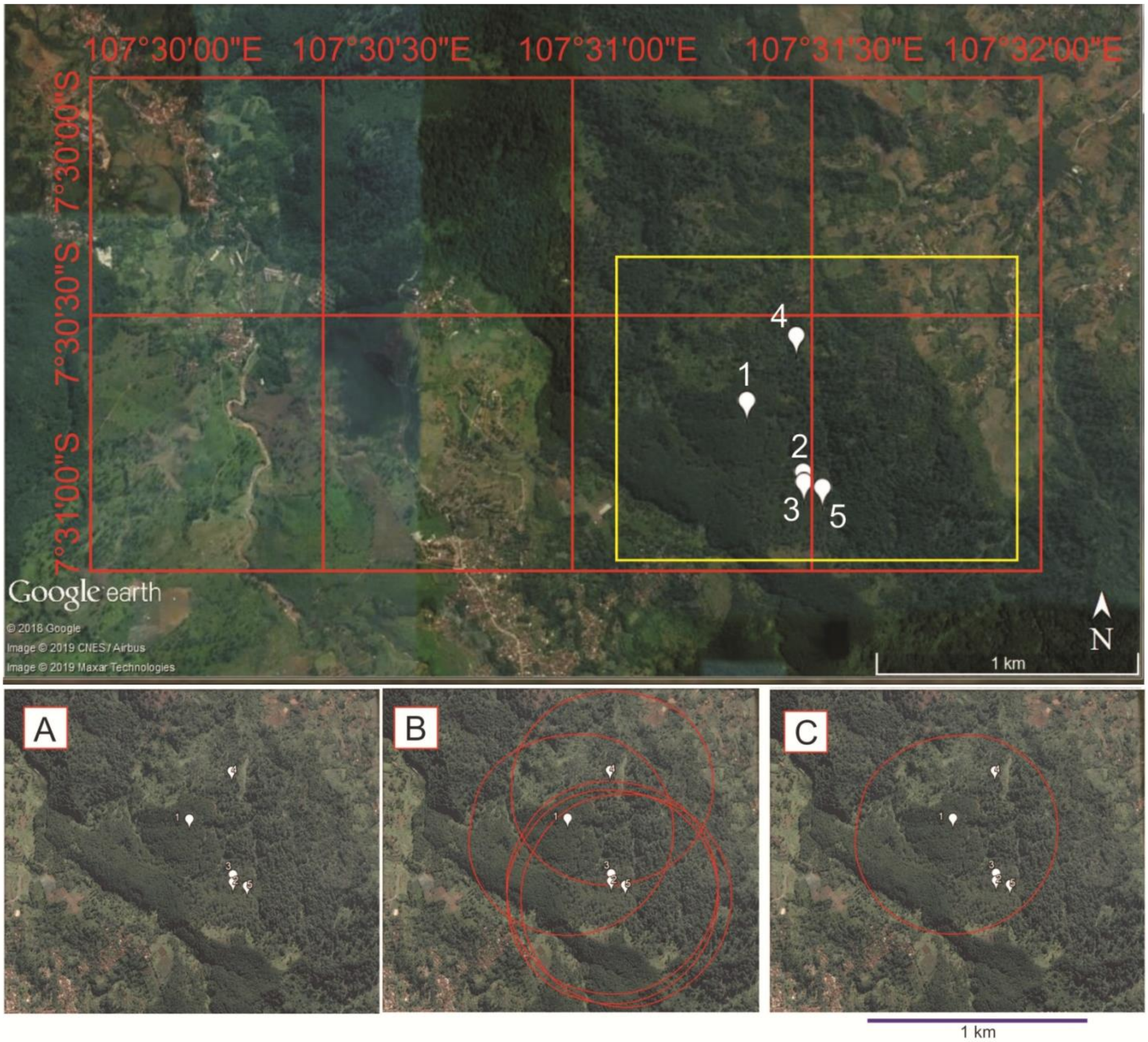

Figure 1. Study sample determination in Pangalengan Subdistrict, Bandung District, Indonesia. Studi Sample Determination: A. Five insect community sampling sites in Tegalega, Lamajang Village, B. Five sampling sites intersect each other in a 500 m radius area, C. One sample site randomly chosen as landscape analysis sample

RESULTS AND DISCUSSION

Landscape characteristics

Based on direct field observation, the landscapes of the natural forests were characteristic of a multi-strata vegetation structure with diverse vegetation composition in each of the strata. In plantation forests, the distance between trees was relatively uniform and the trees planted were *Eucalyptus* sp. or *Altingia excelsa*. Similarly, pine forests also had relatively uniform inter-tree distances.

Mixed gardens were community-cultivated land consisting of various kinds of plants such as vegetables, fruits, bamboo, and medicinal plants, while vegetable gardens were only planted with vegetables. The open fields were tea plantations were a tea production area managed by *Perkebunan Nusantara* VIII, in which tea (*Camelia sinensis*) was planted mono-culturally. Bodies of water were reservoirs for hydroelectric power plants, irrigation canals, and small rivers, and the roads were the West Java Province highway connecting Bandung District and Garut District and footpaths in forested and plantation areas. The settlements in the study were settlements with a large home garden.

In general, land use in each type of land cover at the study location differed based on ownership and use. Land owned by the national electricity company (*Perusahaan Listrik Negara*) was used for hydroelectric power and irrigation, and land owned by *Perkebunan Nusantara* VIII company was used for tea plantations. Perum Perhutani's land was in the form of forests, while community-owned land was in the form of settlements and agricultural land.

There was also other land uses in the Pangalengan area such as dairy processing and geothermal power plants, but these were not included in the sample areas of the landscape analysis.

Landscape metric results of the 17 sample points showed 10 land cover classes. Each sample point had a level of variation in the number of land cover classes that composed it (between 2 and 7 land cover classes indicated by the value of Patch Richness [PR] (Table 2).

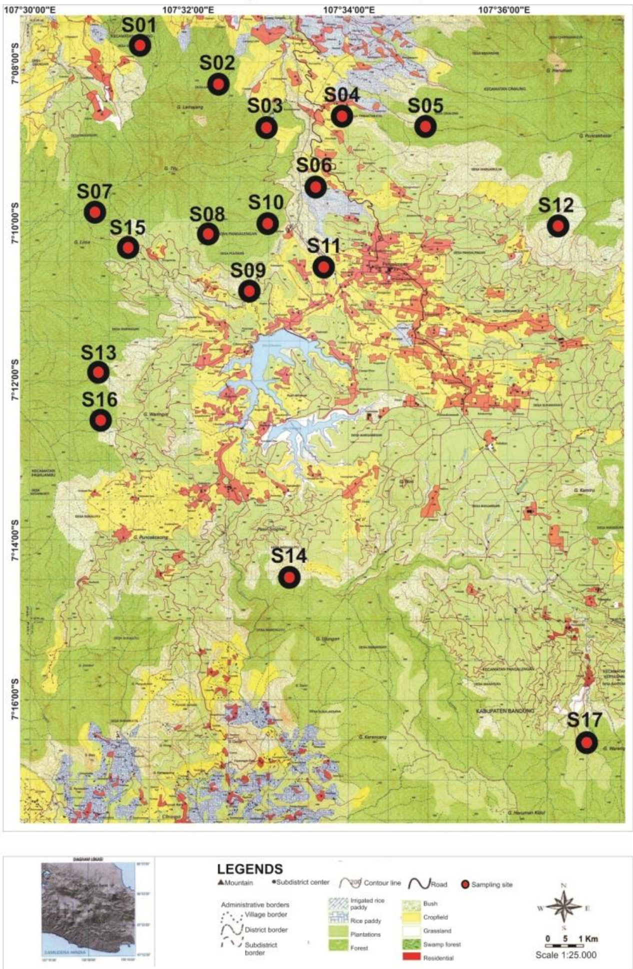

Figure 2. Study location map in Pangalengan Subdistrict, Bandung District, Indonesia (National Coordinator for Survey and Mapping Agency -Indonesia, 1999)

Table 2. Landscape characteristics based on class metrics

Sample code	PR	Class	NP	Area (m^2)	PLAND (%)	Total edge (m)
S01	2	Natural forest	1	604,107.1	76.917	579,713.9
		Mixed garden	3	181,291.1	23.083	307,505.6
S02	2	Natural forest	1	768,548.2	97.855	403,626.1
		Mixed garden	1	16,849.93	2.145	120,449.7
S03	4	Natural forest	1	669,365	85.226	507,324.5
		Mixed garden	2	99,227.99	12.634	230,330.1
		Road	1	2,586.316	0.329	37,092.12
		Body of water	1	14,218.85	1.810	53,843.4
S04	7	Mixed garden	4	340,005.9	43.291	724,492.9
		Natural forest	5	101,243.3	12.891	402,629
		Road	3	13,675.35	1.741	271,011.8
		Settlement	15	62,591.52	7.969	393,655.1
		Body of water	1	509.7234	0.065	8,973.9
		Plantation forest	1	189,496.2	24.127	235,116.2
		Tea plantation	1	77,876.94	9.916	177,085
S05	2	Natural forest	1	479,101.5	61.001	345,794.3
		Mixed garden	2	306,296.6	38.999	475,018.4
S06	7	Natural forest	3	255,813.6	32.571	450,489.8
		Tea plantation	6	345,652.2	44.010	925,508.2
		Mixed garden	3	76,151.42	9.696	333,230.8
		Settlement	5	53,620.7	6.827	216,570.1
		Road	1	10,320.92	1.314	123,241.6
		Open field	4	11,352.93	1.446	87,345.96
		Plantation forest	2	32,486.42	4.136	159,536
S07	2	Natural forest	1	716,182.6	91.187	535,243.3
		Plantation forest	1	69,215.57	8.813	248,876.2
S08	4	Natural forest	2	505,564.7	64.371	630,964.9
		Mixed garden	1	245,523.3	31.261	437,926.3
		Tea plantation	1	32,588.53	4.149	175,489.6
		Road	1	1,720.807	0.219	68,600.48
S09	6	Tea plantation	6	192,296.9	24.484	430,148.9
		Mixed garden	3	80,892.87	10.300	207,596.2
		Natural forest	1	484,066.8	61.633	506,726.2
		Settlement	1	2,227.389	0.284	22,733.88
		Road	2	5,122.367	0.652	101,704.2
		Vegetable garden	2	20,791.85	2.647	82,559.88
S10	4	Natural forest	2	443,416.2	56.458	620,595
		Mixed garden	1	316,660	40.318	720,305
		Open field	2	13,456.23	1.713	76,577.28
		Settlement	1	11,865.8	1.511	73,386.56
S11	6	Vegetable garden	4	313,582	39.927	734,663.3
		Natural forest	4	123,305.9	15.700	362,545.6
		Mixed garden	2	97,369.74	12.398	254,260.5
		Settlement	14	86,992.27	11.076	463,053.2
		Pine forests	1	139,901.4	17.813	378,698.6
		Tea plantation	2	24,246.81	3.087	111,874.6
S12	5	Mixed garden	2	49,6631.6	63.233	546,211.4
		Natural forest	1	28,477.75	3.626	93,926.82
		Pine forest	1	191,096.8	24.331	263,234.4
		Plantation forest	1	44,638.89	5.684	110,079.8
		Tea plantation	1	24,553.12	3.126	60,424.26
S13	5	Plantation forest	1	93,601.4	11.918	203,408.4
		Mixed garden	1	409,269.4	52.110	473,821.9
		Natural forest	1	263,899.3	33.601	366,932.8
		Tea plantation	1	16,905.7	2.153	78,970.32
		Open field	3	1,722,378	0.219	37,490.96
S14	5	Natural forest	1	531,123.9	67.6248	1,011,458
		Garden	3	41,715.64	5.3114	175,489.6
		Mixed garden	1	34,639.99	4.4105	112,472.9
		Plantation	4	172,944.7	22.02	578,318
S15	5	Mixed garden	5	73,326.34	9.336	382,088.7
		Open field	2	89,934.37	11.451	238,506.3
		Tea plantation	3	415,178.7	52.862	901,378.4
		Road	3	11,662.38	1.485	385,279.4
		Natural forest	1	195,296.3	24.866	250,471.5
S16	3	Natural forest	1	595,819.5	75.862	496,954.6
		Tea plantation	1	80,588.92	10.261	177,882.6
		Mixed garden	2	108,989.7	13.877	276,795
S17	3	Natural forest	1	335,691	42.742	361,349
		Tea plantation	1	125,953.5	16.037	186,657.1
		Plantation forest	1	323,753.7	41.222	370,123.5

Note: NP: Number of patched, PR: Patch Richness

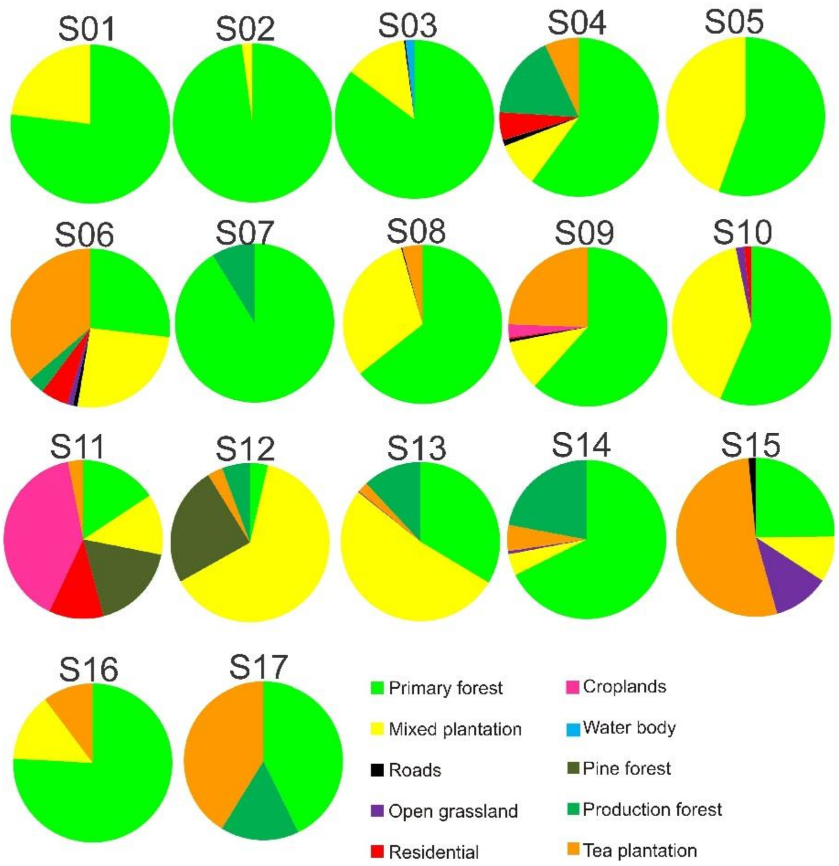

Figure 3. Proportion of land cover class in each sample location in Pangalengan Subdistrict, Bandung District, Indonesia

The number of patches, the area of each class, proportion of landscape, and total edge (TE) can be identified from the results of landscape metrics at the class level in Table 2. The differences in the landscape classes characteristics observed in each sample reflected variations in the landscape processes that occurred in each area. Pie chart representation for comparison of the land cover class composition between samples is shown in Figure 3.

Patch number values can represent the degree of influence of a landscape composition type on the complex processes in that landscape. Among the processes at the micro landscape level is forest fragmentation as indicated by natural forests' NP value >1. Of the 17 sample points, five samples showed natural forest fragmentation with NP values >1. Four of those five samples were located adjacent to each other in the area of Kubangsari, Pulosari Village and Margamulya Village, while one sample was in Talangsari area, Tribaktimulya Village. In four of the five samples, there were patches of settlements, while mixed garden patches were found in the five samples which showed fragmentation of forest land in the area due to land conversion for housing and agriculture.

Forest fragmentation can limit insect habitat space to those types of insects that can only live in the forest. However, the conversion of forest land to agricultural land can be an advantage for other insect species, especially pollinating and herbivorous insects, because this conversion provides support in the form of food sources, thus providing a wider range of roaming territory for these species.

In addition to natural forest fragmentation, NP values can also indicate the intensity of land use on agricultural land and in settlements. Of the 17 study samples, 15 showed mixed garden land cover with NP values >1 in 10 samples. This showed the presence of many agricultural areas in the study landscape. At the time of the study, mixed gardens adjacent to forests were planted with timber-producing trees, bamboo, fruit trees, and vegetables by the community. The existence of this mixed garden later became one of the factors that influenced the spread of insect communities around the forest. The existence of insects on cultivated land is affected by the availability of food and shelter. It is very easy to find flowering plants and wild plants as food sources, especially for pollinators and herbivores on this type of land and the frequency of visits by pollinator communities increases in the flowering and fruiting season (Purwantiningsih et al. 2012).

Landscape characteristics at the class level can also be interpreted by the differences in the proportion of the constituent land cover classes. Natural forests were the largest land cover class with inclusion in twelve samples, whereas mixed gardens had the largest proportion in the three samples, followed by tea plantations with two samples. As seen in the ordination diagram (Figure 4), the proportion of each land cover in the sample showed that the majority of land cover types was geographically clustered, explaining the magnitude of similarities in most samples.

Eleven samples were clustered around the coordinate area of -0.643, 0.392, and -0.193, 0.234. The remaining 6 samples were located far apart; namely sample 2 (0.140, -0.614), sample 6 (0.247, -1.505), sample 15 (0.003, -2,327), sample 12 (0.751, 0.382), sample 4 (0.943, -0,091), and sample 11 (2,869, 0.601). The distance between the coordinate points show differences between samples based on the proportion of land cover composition, similar to the coordinate position of the land cover type. This location was influenced by the percentage of each land cover in the sample and the number of samples that had the land cover. The ordination diagram shows that the variation in the sample based on the proportion of the constituent land cover was relatively similar in the 11 clustered samples and different in the 6 samples.

In addition to the proportion of land cover, the characteristics of each study sample can also be identified based on the value of the edge length (total edge) calculated from the total length of each perimeter of land cover in each sample. The value of total edge shows the amount of connectivity between a land cover class and other land cover classes in the vicinity.

Within land covers which include insect habitats, the connectivity between land cover classes was important because it could affect the distribution of insect communities in the region. For example, there were 3 sample locations composed of natural forest and mixed garden covers, i.e., samples 1, 2, and 5 (Table 4). Based on the total edge cover of mixed gardens, sample 1 was 307,505.6 m edge and sample 2 10,449.7 m edge, while sample 5 was 475,018.4 m edge. This showed that mixed gardens greatest connectivity to natural forests was observed in sample 5, followed by sample 1, and the least connectivity was in sample 2. The large connectivity to the natural forests in samples 5, 2, and 1 affected the number of insects as seen in samples 5, 2, and 1 where more insects were found when compared to other samples.

The value of total edge was influenced by, among other factors, the shape of the patch, the size of the patch, and the number of the patch. In this example, the mixed garden land cover in samples 1, 2, and 5 had an area of 181,291.1 m^2, 16,849.93 m^2, and 306,296.6 m^2 with the number of patches of 3, 1, and 2, respectively. The effect of connectivity between a forest and cultivated land on insect habitat includes limiting insects' roaming range and providing a different type of support between the forest and the cultivated land (Schowalter 2011). The correlation between each sample based on the length of the perimeter class is shown in Figure 5.

Vegetation structure of agroforestry sample

Vegetation analysis was performed through an inventory and based on the vertical stratification rules following (Wildi 2010) on vegetation in agroforestry field samples. Stratification was carried out by classifying the types of vegetation, both natural and those planted by humans, into 5 strata based on their height. The results of the vegetation stratification are described in Table 3.

There were six samples with five vegetation strata each, while the remaining 11 samples had four vegetation strata with two samples not having strata C vegetation and nine samples not having strata A vegetation. There was only one tree species in strata A in each sample: *Pinus merkusii* or *Eucalyptus* sp. In strata B, some species found were those of forest trees, namely: *Pinus merkusii*, *Eucalyptus* sp., *Toona sureni*, *Trema orientalis*, *Schima wallichii*, *Albizia saman*, *Casuarina* sp., *Filicium decipiens*, *Altingia excelsa*, *Ficus variegate*, and horticultural plants *Persea americana*, *Bambusa* sp., and *Pouteria campechiana*.

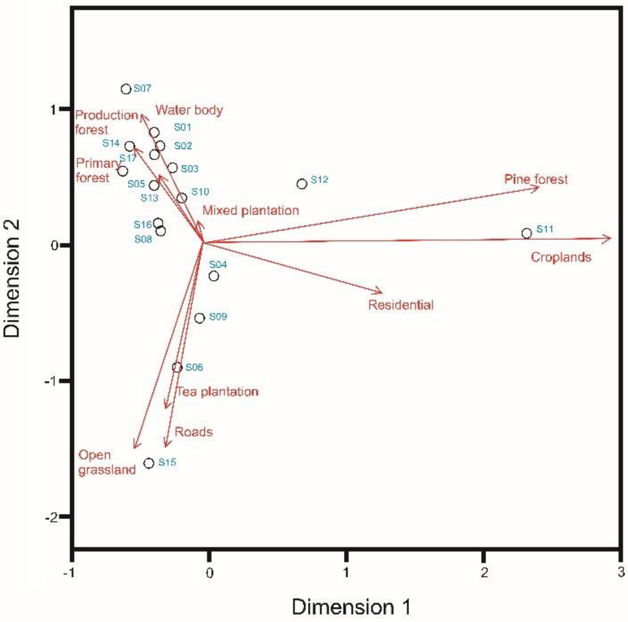

Figure 4. Scatter diagram of sample ordination to the proportion of landscape classes

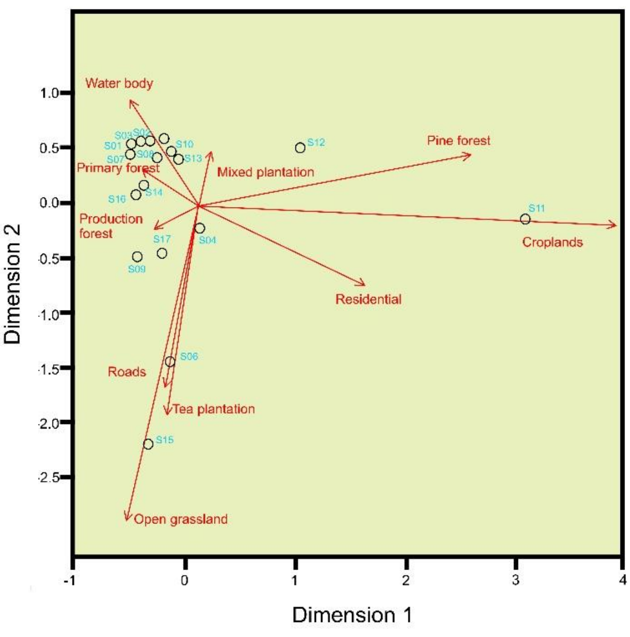

Figure 5. Scatter diagram of sample ordination to the landscape classes, total edge

Table 3. Vegetation stratification at the study site in Pangalengan Subdistrict, Bandung District, Indonesia

Sample code	Strata					Number of strata
	A	B	C	D	E	
S01	+	+	+	+	+	5
S02	+	+	+	+	+	5
S03	+	+	+	+	+	5
S04	-	+	+	+	+	4
S05	-	+	+	+	+	4
S06	-	+	+	+	+	4
S07	-	+	+	+	+	4
S08	-	+	+	+	+	4
S09	+	+	+	+	+	5
S10	-	+	+	+	+	4
S11	-	+	+	+	+	4
S12	-	+	+	+	+	4
S13	+	+	+	+	+	5
S14	+	+	+	+	+	5
S15	+	+	-	+	+	4
S16	+	+	+	+	+	5
S17	+	+	-	+	+	4

In strata C, forest plants found included *Toona sureni*, *Hibiscus macrophyllus*, *Altingia excelsa*, *Eucalyptus* sp., *Pinus merkusii*, *Trema orientalis*, *Calliandra calothyrsus*, and *Chinchona pubescens*. However, strata C was dominated more by horticultural plants such as *Artocarpus heterophyllus*, *Carica papaya*, *Cinnamomum* sp. *Pouteria campechiana*, *Coffea arabica*, *Parkia speciosa*, *Bambusa* sp., *Persea americana*, *Musa paradisiaca*, *Manihot esculenta*, *Psidium guajava*, *Citrus maxima*, *Mangifera indica*, and *Mangifera foetida*.

Strata D was dominated by arabica coffee plants found in all samples and *C. canephora* was found in two samples. Besides coffee, some species found in D strata were *Musa paradisiaca*, *Syzygium malaccense*, *Ageratum conyzoides*, *Persea americana*, *Solanum betaceum*, *Calliandra calothyrsus*, *Bambusa* sp., *Leucanea leucocephala*, *Pennisetum* sp., *Cycas* sp., *Salacca zalacca*, *Solanum torvum*, *Areca catechu*, and *Lantana camara*.

In strata E, some species found were ground cover plants such as *Centella asiatica*, *Marsilea crenata*, *Melastoma malabathricum*, *Ageratina riparia*, *Chromolaeema odorata*, *Impatiens balsamina*, *Cyperus* sp., *Hyptis capitata*, *Rubus reflexus*, *Caladium* sp., *Pennisetum* sp., *Chromolaema odorata*, *Drynaris* sp., *Eclipta prostrata*, *Amaranthus spinosus*, *Cymbopogon citratus*, and horticultural plants such as *Curcuma* sp., *Colocasia esculenta*, *Ipomoea batatas*, *Zingiber officinale*, *Brassica rapa*, *Brassica oleracea*, *Ocimum citriodorum*, *Canna discolor*, *Manihot esculentum*, *Solanum lycopersicum*, *Solanum torvum*, *Camelia sinensis*, *Capsicum annum*, *Capsicum frutescens*, and *Capsicum chinense*.

The landscape characteristics based on vegetation communities in natural forests were similar to those typical of rainforests in the West Java region since the Pleistocene period: rasamala plant species (*Altingia excelsa*) and plants of the Myrtaceae genus were found (Semah and Semah 2012). In addition, the vegetation community was also influenced by PHBM land management patterns by the croppers. In this program, the types of plants planted by the community were coffee (*Coffea arabica*), with main canopy plants such as fruit trees including avocadoes (*Persea americana*), jackfruit (*Artocarpus heterophyllus*), and oranges (*Citrus maxima*). However, the fact that coffee could only be harvested once a year and the waiting period of six years compelled the farming community to plant horticultural plants with shorter intercropping periods on PHBM's land to cover the cost of maintaining the coffee plants and to earn their daily income.

The horticulture plants planted by the croppers were diverse, ranging from vegetables, fruits, food crops, cooking spices, and medicinal plants. Lands with open canopy cover were usually planted with vegetables such as tomatoes, mustard greens, carrots, cabbages, and other types of chili, while lands with a more closed canopy usually had more plants other than vegetables such as sweet potatoes, betel nut, oranges, taro, cassava, bamboo, guava, and chili. This type of land management practice provided more benefits to the community, in that aside from coffee and other horticulture crops, the community could get additional income from firewood in the forest and forage for animal feed.

Even though it was economically profitable, the practice of intercropping on PHBM land had negative consequences for the environment, especially on lands that were intensively planted with vegetables. In addition to removing the ground cover plants where insects lived, spraying pesticides on vegetable plants also reduced the number of insects. The administration of synthetic and biological pesticides reduces the diversity of insects (Shannon-Wiener index value [H '] of <1, which shows very low diversity) (Sanjaya and Dibyantoro 2012). In addition to the negative impact on the insect community, intercropping practices can also adversely affect the soil structure of the land because tillage is needed when planting seasonal crops. This includes cleaning up wild plants, plowing during planting, and harvesting, which increases soil porosity and increases the risk of erosion due to water runoff.

Landscape metrics in study samples

Landscape metrics were used to compare landscape characteristics between samples, and the metrics used were Shannon's Diversity Index (SHDI), Patch Richness (PR) and Largest Patch Index (LPI) (Table 4).

The SHDI value showed the level of sample heterogeneity at the landscape level varied between 0.104 to 1.476. The SHDI value in the sample was related to the number of classes indicated by both the PR and the LPI value, displaying dominance by one of the largest landscape classes. Samples 1, 2, and 5 had SHDI values of 0.540, 0.104, and 0.669 respectively and LPI values of 76.917, 97.855, and 61.001. These three samples had a PR value of 2, but there were differences in the value of SHDI, which increased with decreasing LPI values. This difference also occurred in other samples with a larger PR value, with SHDI increasing in samples with a greater LPI value.

Relationships between landscape characteristics and insect communities

To determine the relationship between the characteristics of the landscape and the insect community, a linear regression test was conducted. The variables of the landscape characteristics tested were Shannon's Diversity Index (SHDI), Number of Patches (NP), and the proportion of natural forests as land cover found in all samples. The insects community data used were the number of insect species found in Table 5. Data on the number of insect species were then tested against the characteristics of the landscape using linear regression with results shown in Table 6.

Table 4. Landscape metrics in study samples in Pangalengan Subdistrict, Bandung District, Indonesia

Sample code	SHDI	PR	LPI	LP
S01	0.540	2	76.917	Natural forest
S02	0.104	2	97.855	Natural forest
S03	0.489	4	85.226	Natural forest
S04	1.476	7	43.291	Mixed garden
S05	0.669	2	61.001	Natural forest
S06	1.386	7	44.010	Tea plantation
S07	0.298	2	91.187	Natural forest
S08	0.793	4	64.371	Natural forest
S09	1.023	6	61.633	Natural forest
S10	0.822	4	56.458	Natural forest
S11	1.575	6	39.927	Vegetable garden
S12	1.025	5	63.233	Mixed garden
S13	1.056	5	52.110	Natural forest
S14	0.923	5	67.6248	Natural forest
S15	1.215	5	52.862	Tea plantation
S16	0.717	3	75.862	Natural forest
S17	1.022	3	42.742	Natural forest

Table 5. Number of insect species at the sample points in Pangalengan Subdistrict, Bandung District, Indonesia

Sample code	Number of species	Order	Number of orders
S01	6	Coleoptera	5
	13	Diptera	
	4	Hemiptera	
	9	Hymenoptera	
	6	Lepidoptera	
S02	4	Coleoptera	6
	7	Diptera	
	1	Hemiptera	
	14	Hymenoptera	
	9	Lepidoptera	
	1	Orthoptera	
S03	10	Diptera	5
	14	Hymenoptera	
	4	Lepidoptera	
	1	Odonata	
	1	Orthoptera	
S04	4	Coleoptera	6
	8	Diptera	
	4	Hymenoptera	
	3	Lepidoptera	
	2	Odonata	
	1	Orthoptera	
S05	5	Coleoptera	5
	12	Diptera	
	7	Hymenoptera	
	5	Lepidoptera	
	4	Odonata	
S06	3	Coleoptera	4
	9	Diptera	
	6	Hymenoptera	
	3	Lepidoptera	
S07	5	Coleoptera	6
	11	Diptera	
	6	Hymenoptera	
	4	Lepidoptera	
	2	Odonata	
	1	Orthoptera	
S08	9	Diptera	3
	6	Hymenoptera	
	3	Lepidoptera	
S09	4	Coleoptera	5
	8	Diptera	
	6	Hymenoptera	
	3	Lepidoptera	
	1	Odonata	
S10	5	Diptera	4
	7	Hymenoptera	
	10	Lepidoptera	
	3	Odonata	
S11	8	Diptera	3
	9	Hymenoptera	
	3	Lepidoptera	
S12	3	Coleoptera	4
	9	Diptera	
	12	Hymenoptera	
	9	Lepidoptera	
S13	4	Coleoptera	4
	7	Diptera	
	4	Hymenoptera	
	6	Lepidoptera	
S14	7	Coleoptera	4
	8	Diptera	
	7	Hymenoptera	
	3	Lepidoptera	
S15	1	Coleoptera	4
	9	Diptera	
	13	Hymenoptera	
	4	Lepidoptera	
S16	6	Diptera	5
	7	Hymenoptera	
	12	Lepidoptera	
	1	Odonata	
	2	Orthoptera	
S17	1	Coleoptera	5
	9	Diptera	
	2	Hemiptera	
	6	Hymenoptera	
	9	Lepidoptera	

Table 6. Simple linear regression test results of landscape characteristics to the number of insect types

Independent variable (Y)	Correlation coefficient (R)	Determination coefficient (R^2)	Significant F-change
SHDI	0.675	0.456	0.003
PR	0.717	0.514	0.001
Proportion of natural forests	0.388	0.150	0.124
SHDI, PR, Proportion of natural forests	0.829	0.687	0.001

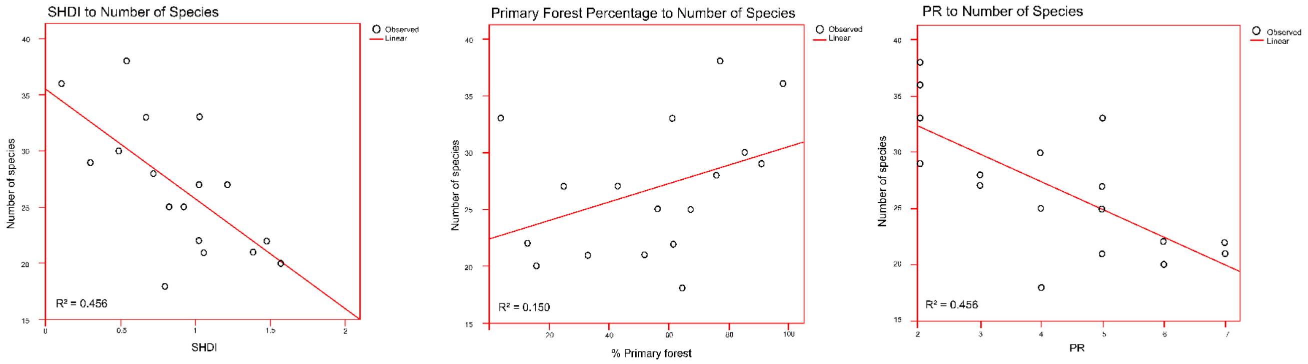

Figure 6. Linear regression curve of landscape characteristics to the number of insect species

The results of the simple linear regression of the landscape characteristics to the number of insect species showed that the independent variable (Y) SHDI and PR correlated while the proportion of natural forests did not correlate. Shannon's diversity index, PR, and the proportion of the natural forests were simultaneously related to the dependent variable (X, the number of insect species) based on decision making through the F-change significance value, where if significant, F-change <0.05. The closeness of the correlation between the independent and dependent variables was observed from the R coefficient value based on the Pearson's degree of relations guidelines. The correlation coefficient values in the independent variables SHDI and PR were 0.675 and 0.717, respectively which meant that the correlation was strong, while the three independent variables simultaneously showed a very strong correlation (R=0.829). Meanwhile, the proportion of natural forests showed a weak correlation (R=0.388).

The three landscape characteristic variables showed a greater correlation coefficient when tested simultaneously with the dependent variable as the number of insects. The correlation between the three variables of landscape characteristics to the number of species of insects is shown in Figure 6.

From the study data, it was found that the variables SHDI, PR, and the proportion of the natural forests land cover had R^2 values of 0.456, 0.514, and 0.150, respectively. The graph can also show whether the relationship between the independent variable and the dependent variable is a positive or negative value by the beta coefficient value.

The variables SHDI and PR showed a negative correlation with the number of insect species, which meant that increases in SHDI and PR would reduce the number of insect species. This could be due to the differences in land cover around the coffee agroforestry land sample. Samples located in the Kubangsari and Margamulya area that were close together had the diverse land cover and tended to have fewer species of insects, between 18 and 25 species from 3 to 5 orders. Samples in the Lamajang area with had fewer land cover classes and were dominated by natural forests had 30 to 38 species from 5 to 6 orders. This showed that the increasing level of landscape diversity occurring because conversion of forest land could reduce the number of species of insects in a given area.

Changing forest land into agricultural land and settlements will certainly change the physical condition of the environment in the region so that the distributions of insects are affected greatly. Insects are homeothermic animals, and one physical environmental factor that greatly influences the spread of insects is temperature: an increase in air temperature will increase the rate of insect metabolism, due to increased eating activity and thereby movement. In addition, a significant increase or decrease in water temperatures can also increase the mortality rate of insect larvae living in the water (Schowalter 2011). Insect communities in the Pangalengan region, a mountainous area with cold temperatures, can be affected by sunlight which can increase the air temperature in more open areas resulting in an increase rate of insect metabolism and mortality of insect larvae.

Landscape composition also affects the spread of insects depending on the availability of each habitat element in the landscape. Each group of insects responds differently to landscape composition. In addition, insects can also respond differently to structures in a landscape. Herbivorous insects tend to be found in large patches as opposed to small patches while predatory insects are more abundant in non-isolated patches than in isolated patches in agricultural areas (Zabel and Tscharntke 1993).

The differences in land covers between natural and human-built land also affect the distribution of insect species, in which insects (i.e. *Apis cerana*) demonstrating high tolerance to human presence will occupy built habitat while the distribution of insects with low tolerance will be limited to natural habitats (i.e. *Troides helena*). In this study, insects belonging to the orders Diptera, Hymenoptera, and Lepidoptera were found in all study samples while insects from orders Hemiptera, Odonata, and Orthoptera were least found in the fewest samples. Insects from the orders Diptera, Hymenoptera, and Lepidoptera are generally included in the functional groups of pollinating insects, although some groups of Diptera in the larval and adult phases are included in decomposing insects. Hymenoptera, such as in the family Vespidae, are predators and the larvae of Lepidoptera are plant eaters. The group of pollinating insects is further divided into specific pollinators and opportunist pollinators (Schowalter 2011). Specific pollinators such as honey bees (family Apidae) will only pollinate certain plants or plants such as coffee (*Coffea* spp.) or kaliandra (*Calliandra* spp.). Meanwhile, opportunist pollinating insects such as butterflies from the family Nymphalidae tend to pollinate any plants found, from understory, shrubs, to cultivation plants (Budumajji and Raju 2018).

The orders Hemiptera and Orthoptera include mostly plant-eating functional groups (herbivores) which prefer areas with vegetation dominated by shrubs with little canopy cover (Schowalter 2011). This might be a limiting factor in their distribution because of the small number of open lands in the study sample location. The order Odonata belongs in the functional group of predatory insects, whose numbers are fewer than the number of their prey insects. In addition to a large roaming range, Odonata larvae need water sources as a habitat which can also become a factor that limits their distribution (Schowalter 2011).

The natural forest cover proportion variable based on the value of significance F-change was not correlated and had a weak correlation coefficient (R) with the number of species of insect. The low correlation coefficient value could be caused by the irregularity of data distribution, forcing it far from the regression line. The presence and connectivity to other land caused ambiguities in the correlation of the proportion of natural forests to the number of insect species, but this could also be due to other natural forest characteristics such as the number of patches and the total length of edges in each sample that could demonstrate fragmentation in the forests.

Characteristics of the landscape samples based on the patch diversity variable, the number of patch types, and the proportion of natural forests show the degree of natural forest fragmentation, as natural habitats of insects, caused differences in the number of species based on the adaptability of each species to habitat disturbance. Meanwhile, the variable proportion of natural forests can also show the connectivity between natural insect habitat and other land covers. More connected habitats allow the possibility of insect movement from natural habitats to human-built land and disturbance to habitats to be higher so that there are fewer species of insects.

To summarize, this study set out to assess the landscape characteristics of coffee agroforests in the Pangalengan Subdistrict and analyze how those characteristics influence the insect communities using landscape metrics approaches. In relation to the landscape characteristics and based on their composition, it was found that there were 10 classes of land cover found in the coffee agroforestry in the Pangalengan subdistrict. The calculation of the vegetation structure of the agroforestry showed that there were six samples having five vegetation strata, while the other 11 samples had four. The landscape characteristics seen from the vegetation communities in natural forests at the study site were similar to the typical characteristics of rain forests in the West Java region. In addition, the vegetation community at the study site was influenced by the land management patterns of the coffee farmers.

From the calculation of the linear regression test, it was found that the characteristics of the coffee agroforestry landscape were related to the distribution of insect communities in that a high diversity of landscapes, characterized by the value of Shannon's diversity index, strongly negatively influenced the number of insect species, which could be caused by the increase of landscape diversity because of the conversion of forest land into agricultural land and settlement resulting in the reduction of the number of insects living in it. Similarly, the number of land cover classes, indicated by the value of number of patches, had a strong, negative influence on the number of insect species, which could happen as insects gave different response to a particular landscape structure. However, the proportion of natural forest land cover in the sample has a positive effect on the number of insect species with a weak correlation.

ACKNOWLEDGEMENTS

This study was supported by the Indonesian Ministry of Research Technology and Higher Education, through *Penelitian Terapan Unggulan Perguruan Tinggi (PTUPT).* The authors would like to thank to Fakhrur Rozi with the field team for collecting the data of insect and Fathimah Noorahya for assisting the author to prepare the manuscript. We also thank to research team who identified all insect species.

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