Landscape structure and parasitoid diversity as measures of sustainable landscape

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Abstract: Complexity and structure of a landscape influence the presence of insect parasitoids in agricultural landscapes. Landscape structures are often formed from semi-natural habitat fragmentation, which can reduce the richness and abundance of insect parasitoid and affect their ability to suppress pest population. This study was aimed to study the effect of landscape structure on the diversity and abundance of insect parasitoids in long beans fields. In six agricultural regions, landscape parameters were calculated, i.e class area (CA), a number of patches (NumP), and mean patch size (MPS). Insect samplings were conducted using transect methods and direct collection. Results of landscape complexity did not affect the species richness of parasitoid, but it did affect the species composition. The results showed that the higher the CA of the tree, the higher the percentage of parasitization, but the higher the CA of agriculture, the lower the percentage of parasitization. This shows that there are landscape parameter indicators that can be used as a key to see the presence of parasitoids so that they can provide an indication of sustainability. Therefore, landscape structure must consider the importance of landscape management habitats for the conservation of natural enemies especially insect parasitoid as a biological control agent to create sustainable landscapes.

Keywords: landscape parameters, conservation, natural enemies

1. Introduction
Multifunctional landscapes, which promote provide favorable conditions and biodiversity for agriculture based on ecological principles, may contribute to the development of productive yet sustainable agricultural systems [1]. The structure and function of landscapes composed of agricultural land, plantations, industries, and housing often occur in the transformation of natural habitats resulting in habitat fragmentation. Fragmentation of natural habitat is one of the factors causing the reduced diversity of insect species [2]. Complex landscapes, dominated by a high proportion of natural habitats (or semi-natural habitats) while simple landscapes consist of monoculture plants [3]. The heterogeneity of agricultural landscapes is formed based on the proportion of semi-natural habitats that have an important role and function for insect diversity. The purpose of semi-natural habitats in landscape heterogeneity as a place to provide feeding, nesting, and direction of insect-spread [4].

The complexity and structure of the landscape and the heterogeneity of semi-natural habitats influence the presence of insects in an agricultural landscape. Previous studies have shown that the diversity and abundance of pollinating insects, such as solitary bees and social bees are influenced by landscape structures.
[5], [6] reported that the abundance of butterflies increased with increasing habitat diversity around the landscape. Other studies show that complex landscapes with a high proportion of semi-natural habitats have a higher diversity of insects both natural enemies and other beneficial insects. The increasing complexity of the landscape also affects the wealth and abundance of Syrphidae species [7].

However, several types of plants affect the diversity of insects in agricultural landscapes for both insect pests and beneficial insects (e.g. natural enemies and pollinators). In the case of vegetable plants with insect pests. The natural habitat itself is composed of several lands uses including agricultural land, plantations, industrial land, housing, and various other human needs. The expanse of land or a heterogeneous area consisting of various habitats, both natural and man-made with different areas known as landscapes. Different landscape structures can form landscapes into complex and simple landscapes. The proportion of natural habitats in a landscape can affect landscape complexity [8]. Simple landscapes are characterized by a smaller proportion of non-agricultural crops with heterogeneous tend to plant vegetation, while complex landscapes have a dominant non-agricultural crop in a landscape [9].

The diversity, abundance, and effectiveness of parasitoid in it is much influenced by the landscape structure of a farm [10]. The complexity of a landscape affects the species richness of insects. Simple landscapes tend to have a lower diversity of natural enemies compared to complex landscapes [11]. In other research, the landscape the percentage complex of parasitization of *Meteoris communis* (Hymenoptera: Braconidae) to *Pseudaletia unipuncta* (Lepidoptera: Noctuidae) is higher (13.1%) than in a simple landscape (2.4%). Landscape natural habitat has an important role in pest control. Agricultural landscapes have simple plant complexity and low diversity of plant species so that applying good landscape management can create conditions such as natural or semi-natural habitat, while landscapes supported by natural or semi-natural habitats function as alternative host sources and prey, sources of nectar, refugium for natural enemies to prevent damage to crops [12].

Research on pest and parasitoid insects in Indonesia has been carried out but is still limited to data collection and communities of pest and parasitoid insects so that this lack of information needs to be explored. One of the suitable plant models in this research is long bean plants. Long bean plants are one of the crops throughout the season which are widely used for consumption and as green manure and cover crops to prevent soil erosion [13]. In the harvest period, long bean plants are attacked by pests which can reduce economic value.

This study is expected to provide information on the diversity and abundance of pest and parasitoid insects in long bean plantings in several landscape structures, the relationship of landscape parameters to the diversity and abundance of pest and parasitoid insects. This information can be used as a basis for designing strategies for conservation of natural enemy insects, in this case, are insects that act as controlling pests (parasitoid) in long bean plantations, especially in West Java.

2. Materials and methods
This research was conducted in July 2016 until February 2017. Observations were carried out in 6 locations of long bean plants spread in Bogor Regency. Identification of pest and parasitoid insects was carried out at the Biological Control Laboratory, Department of Plant Protection, Faculty of Agriculture, Bogor Agricultural Institute.

The study was conducted on two types of landscapes, namely: S (simple) and K (complex). Each landscape type consists of 3 long bean crop fields. Some of the criteria used in determining the location include the extent of natural habitat, the altitude of the place, a distance between locations of at least 2 km and a land area of 25 m x 50 m.

2.1. Landscape type observation
Observation of landscape type begins by marking the location of the research using the global positioning system (GPS) to get the coordinates of each research location, then coded according to the location name. Points of coordinates obtained, inputted to Google Earth to get a map of the research location. Then do ground check by recording the planted agricultural commodities and vegetation of trees around the land in each landscape, carried out at a distance of 500 m.
The results of the ground check mapping are then mapped digitally using the QGIS soft trap. The calculated landscape parameters include: (1) Class Area (CA), (2) Number of Patches (NumP), (3) Total Edge (TE), (4) Mean Patch Size (MPS). The value of the landscape parameters produced, then used for grouping landscapes. The landscape parameters used in grouping landscapes are CA and NumP from three types of land use, namely trees, agriculture, and housing.

2.2. *Taking examples of insects parasitoid*

The sampling of pests and long bean parasitoid insects was carried out using direct observation and collection methods. Observations were made on long been planting the land with an area of 25 m x 50 m. Age of long bean plants observed ranged from 7-49 hst (days after planting). The sampling of the parasitoid was carried out at 06.00 WIB. Observations were made on 100 right-left plant units on each transect. The long bean plants observed were plants facing the transect pathway. On each transect, the number of insect parasitoid perches on long bean plants is calculated and collected to be maintained in the laboratory. Insects that perch on long bean plants are captured by hand or plastic, while small insects such as ants and trips are collected directly using a brush. The insects obtained are put in a film bottle containing 70% alcohol. The types of insects obtained are then identified in the laboratory.

2.3. *Data analysis*

Data obtained are tabulated into pivot tables. Then analyzed to see several parameters. The frequency of pest insects is calculated based on the presence or absence of pests in each individual plant observed. The effect of landscape complexity on the diversity and abundance of pest and parasitoid insects in each landscape type was analyzed using the General Linear Model (GLM procedure) analysis and displayed in boxplots. The landscape parameters seen in this study are tree trees, agricultural CA and TE trees. Furthermore, these three landscape parameters were then correlated with the diversity and abundance of insect species and long bean parasitoid.

3. *Results and discussion*

3.1. *Diversity and abundance of insect insects and parasites*

Pest insects that have been collected in this study amounted 13 to 192 individuals, consisting of 41 families and 44 species. The results of the study found three morphospecies of the dominant pest, *Aphis* sp. (Hemiptera: Aphididae) with 4 755 individuals, *Crambidae* 01 (Lepidoptera: Crambidae) with 1 409 individuals, and *Noctuidae* 01 (Lepidoptera: Noctuidae) having 973 individuals. Noctuidae is a family whose members attack many bean plants, but from the total individuals, Aphididae is the most dominant family associated with long bean plants. *Aphis* sp. is a pest insect found in all research locations with an abundance of 793 individuals per location shown in Figure 2.
Plant age affects the abundance and diversity of pest species that attack long bean plants. At the time of 1-week-long bean plants, 19 species of pests were found. While at the time of 7 weeks old bean plants, the number of pest species that attacked the plant consisted of 38 species. The abundance of pests in simple and complex landscapes increases with increasing age of long bean plants.

Figure 1. Abundance (top) and diversity (bottom) of long bean pests on different landscapes and plant ages.

Figure 2. The composition of long bean pests on different landscapes and plant life.
Based on the analysis conducted, it is known that landscape complexity does not affect species richness ($F_{1,4} = 81.00, P = 0.0704$) and pest abundance in long bean crops ($F_{1,4} = 167.04, P = 0.0495$) (Table 1).

This is presumably due to the increasing proportion of non-agricultural crops. Non-agricultural crops are providers of resources such as food, alternative host sources, shelter or providing nests. The research conducted by [3] state that complex landscapes have higher diversity and abundance of Braconidae parasitoid than simple landscapes. The existence of tree habitat which is an indication of natural habitat is the primary source in providing food sources and shelter for insect pests and parasitoid. Provision or management of natural habitats around agricultural land such as forests can also maintain insect diversity including natural enemies and other useful insects.

| Type of landscapes | Family | Species/ morphospecies | Statistic | Number of individuals | Statistic |
|-------------------|--------|------------------------|-----------|-----------------------|-----------|
| Pest              |        |                        |           |                       |           |
| Simple            | 27     | 35                     | $F_{1,4} = 81.00$ | 5 295                 | $F_{1,4} = 167.04$ |
| Complex           | 32     | 38                     | $P = 0.0704$     | 7 417                 | $P = 0.0495$     |
| Total             | 35     |                        |            |                       |           |

The abundance of pest and parasitoid insects in a habitat is influenced by several factors such as food sources, namely pollen, and nectar, as well as environmental factors. Based on the data presented in Figure 2, it can be seen that the complexity affects the abundance of pest insects at the time of observation in both types of landscapes. It is seen that the number of individual pest insects found in complex landscapes increases and the simple landscape of abundance decreases.

3.2. Parasitoid associated with pest insects in long bean plants

A total of 1 667 imago Aphis sp., Crambidae 01 larvae, and Noctuidae 01 were found to be parasitic by 18 parasitoids. The number of parasitoid images that have emerged from these parasitic pests is 2 431 primary parasitoid individuals. Pest Aphis sp. parasitized by 18 species of parasitoid imago (family Encyrtidae and Braconidae). Crambidae 01 was found parasitized by ten species of the larval parasitoid (Braconidae and Ichneumonidae) and eight species of pupa parasitoid (Eulophidae). Noctuidae 01 larvae were parasitized by 17 parasitoid species Braconidae and Eulophidae (Table 2).
Figure 3. Abundance (top) and diversity (bottom) of long bean parasitoid on different landscapes and plant life.

Landscape complexity affects the species richness of parasitoid insects in long bean plants ($F_{1,4} = 4.00$, $P = 0.2952$), while the abundance of these parasites tends to increase with increasing landscape complexity ($F_{1,4} = 1.87$, $P = 0.4017$) (Table 2).

| Type of landscapes | Family | Species/morphospecies | Statistic | Number of individuals | Statistic |
|--------------------|--------|------------------------|-----------|-----------------------|-----------|
| Parasitoids        |        |                        |           |                       |           |
| Simple             | 12     | 46                     | $F_{1,4} = 4.00$ | 1 445                 | $F_{1,4} = 1.87$ |
| Complex            | 11     | 39                     | $P = 0.2952$  | 1 220                 | $P = 0.4017$  |
| Total              | 12     |                        |           |                       |           |
3.3. Differences in the composition of pest and parasitoid insects in different landscapes

The composition and species richness of pests in each landscape has no difference. The composition and wealth of pest species are considered more able to describe differences in landscape structure compared to only the number of insect pest species. What one of the frequently used beta-diversity analyzes is the NMDS analysis, which is to determine the relationship between the diversity of pest insects found in different landscapes around long bean crops. NMDS was obtained from an analysis based on the Bray-Curtis index, which is to find out the level of difference between landscapes and further tests using similarity analysis (ANOSIM).

However, statistically (ANOSIM statistics R= 0.275, P = -0.04422) were not significantly different, the composition of species between landscapes tended to differ based on group separations seen in the NMDS analysis (Figure 5). The difference is due to the complexity of the landscape around different bean plants. In contrast to parasitoid insects presented in Figure 4, it can be seen that complexity does not affect diversity in both types of landscapes, but affects the abundance of parasitoid insects found in increasing complex landscapes compared to simple landscapes.

![Figure 5. NMDS from the composition of insect pests (A) and parasitoid (B) based on the Bray-Curtis index. The code contained in the picture shows the study area: K= Complex; S= Simple, the number indicates the age of the plant.](image-url)
4. Conclusion
In conclusion, landscape parameter indicators that can be used as a key to see the presence of parasitoids so that they can indicate sustainability. The difference in composition is affected by the existence of trees in the landscapes. Landscape structure must consider the importance of landscape management habitats for the conservation of natural enemies especially insect parasitoid as a biological control agent to create sustainable landscapes.

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