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# INSECT AS BIOLOGICAL INDICATOR FROM PROTECTED TO THE DISTURB LANDSCAPE IN CENTRAL JAVA INDONESIA

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## ABSTRACT

In the biological science, invertebrate (especially insect) diversity is relatively well known. Yet, little study about their interaction with specific land use or specific system function. With the rapid changes of landscape, biodiversity is also changes in response to human impact; due to each organism have the specific interaction with certain environment. In this research, the assessment of insect order in the different landscape types was conducted using several method of trapping to understand the specific pattern of insect which are inhabited the landscape. The objectives of this research were monitored the Insect diversity, its ecological importance to agro-forestry ecosystem, and compare it with other forest type in this area. Another objective was determined the insect characteristic as the indicator of environmental quality on each land-use system (forest, agro-forestry, plantation and monoculture). Monoculture agriculture has the largest number of Lepidoptera and Hemiptera order (herbivore insect dominated) while in agro-forest system has the largest number of Diptera and coleoptera order. Protected forest, plantation forest and agro-forestry showed the similar index number which shows the similar ecological services for the insect as their habitat. However, in the monoculture agriculture, there was an unbalance insect composition and high dominance.

Keywords: landscape, biodiversity, environment indicator index

## INTRODUCTION

Java's landscapes are dominated by agriculture land-use systems, with patches of forest mainly on the dry highland. However, their contribution to the conservation of biodiversity is largely unknown. With the rapid changes of landscape, biodiversity is also changes in response to human impact; due to each organism have the specific interaction with certain environment. In this research, the assessment of insect order in the different landscape types was conducted using several method of trapping to understand the specific pattern of insect which are inhabited the landscape.

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Many invertebrate (especially insect) diversity are relatively well known. Yet, little study about their interaction with specific land use or specific system function. Further insect actually have two properties which are important for the monitoring of ecosystems: their short life-cycle and their low resilience (Luchman *et al.*, 2005). Although these may give some difficulties in determining the turnover rates and judging the establishment of inventory baseline (Brown and Hutchings, 1997). Further, it is not easy to evaluate the economic sustainability of forest products based on the insect parameters due to their high sensitiveness to the environment changes. However, insect still represent an efficient and easily observed early warning system for subtle changes in the whole system, or in the sustainability of its use.

Phytophagous insects are especially tightly tied into light structure, humidity, nutrient availability, and specific plant growth cycles, chemical compounds, and taxonomy, and thus indicate fluctuations in all these elements in the system that supports them. Any change in their abundance will immediately imply an increase or decrease of their primary plant resources, their habitat, or their enemies. Perversely, scavenger insect highly related with the forest litter and the understory plant (Hellawell, 1986; Spellerberg, 1991; Meffe and Carol, 1994; Dufrene and Legendre, 1997).

Hence, the insect was chosen as the indicator due to their richness and easy to access compare to another organism among taxonomic groups. Number of insect order of Hemyphtera, Lepidophtera, Coleophtera, Diphtera, Isophtera, Neuroptera were easily found on the research site and were characterize a gradient from protected forest, agro-forest and annual crops. As expected, Leksono *et al.,* (2005) stated that overall species richness tended to decrease within this gradient of increasing habitat modification, but in the moderate disturbance showed higher species richness. Although biodiversity of land-use systems showed taxonomic group and specific differences, most groups and order were affected in a similar way by habitat modification. Near-primary forest sites proved to be of principal importance for conservation; however, land-use systems such as plantation forest and agro-forest systems supported relatively high numbers of species and play a significant role for the biodiversity poles to the wider landscape.

## MATERIALS AND METHODS

The study was conducted on Wonogiri Regency and Pacitan Regency (Figure.1) focusing on the Wuryantoro district which has the slope and sequence landscape changes from protected forest to seasonal highland rice-field. The research conducted during the rainy season in 2008 (from October 2008 to February 2009).

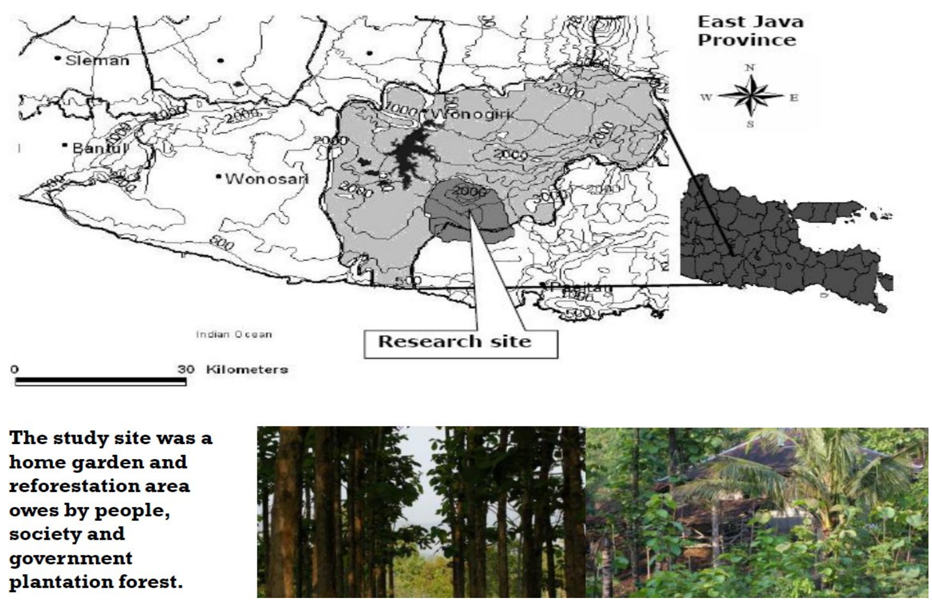



Figure 1. Map and pictures showing the situation of the research site.

The research sites were ranging from rocky and hilly area to relatively flat area, with annual precipitation was ranging from 750 – 1000 mm. The wet months was identified from July to September. The research site was divided into four land-use type; the protected forest is mainly dominated with *Pinus merkusii* managed by Indonesian ministry of forestry, below that was the *Swietenia mahagoni* plantation forest managed by states forestry company (PERHUTANI). The area below those forests was the mix forest (agro-forestry) owns by community or private forest farmer, dominated by teak (*Tectona grandis*), mahagony (*Swietenia mahagoni*), Sengon (*Albizia falcata*), and Lamtoro (*Leucaena glauca).* The most flat area was the dry-land rice-field managed by local farmer (Wicaksono *et al*., 2010)

**Trapping Methods**

The ideal monitoring trap for use in structures should be inexpensive, easy to use, sturdy, reusable, and be free from oil and food baits. The modified Malaise trap (Figure 2).

Tent-like structure used for as a basic designed trap. The trap is made of a material such as terylene netting with the white color. Trapped insects fly into the tent wall and are funneled into a collecting vessel attached to highest point.

For the protected forest, plantation forest and agro-forest, the trapping will be based on several designated trap which are:

- Night ground net trap with / without - light
- Night canopy net trap with / without - light
- Day ground net trap
- Day canopy net trap

For the monoculture rice-field, the trapping will be based on five traps which are:

- Ground net trap with light
- Ground net trap without light
- Sweep netting
- Yellow pan trapping
- Hand searching

To collect specimens for this experiment, all trapping method was replicate 3 times and arranged on the each of land use. Each trap was filled with rotting fruit and vegetables for 24 hours period. The traps were checked twice a day, once at 7:00am and again at 6:00pm. All of the collected specimens were brought back to the lab for identification down to order level. Subsequent statistical analyses were conducted using R software, version 2.7.0.

**Analysis**

Descriptive statistics was employed in this research to determine the relative density of each insect indicator to specific landscape. Simultaneously the Shannon wiener diversity index, Simpson's dominance index and Evenness index was also performed to compare each of land-use type using the insect as the indicator.

Figure 2. The Malaise trap on the research ground and the scheme of Malaise trap

**Shannon Wiener Diversity Index**

The Shannon index or Shannon-Wiener index is one of index, used to measure diversity in categorical data. It is simply the Information entropy of the distribution, treating species as symbols and their relative population sizes as the probability. The advantage of this index is that it takes into account the number of species and the evenness of the species. The index is increased either by having additional unique species, or by having greater species evenness.

$$H' = -\sum_{i=1}^{S}(p_i \ln p_i) - [(S-1)/2N \quad 1)$$

Where:

- $n_i$ The number of individuals in species i; the abundance of species i.
- *S* The number of species. Also called species richness.
- *N* The total number of all individuals
- $p_i$ The relative abundance of each species, calculated as the proportion of individuals of a given species to the total number of individuals in the community: ni/N

**Simpson's Dominance Index**

Simpson's dominance index is a crude indicator of the extent to which a few groups such as species, demographic groups or companies dominate an environment, the total share taken by the top *n* species or firms. Simpson's Index is considered a dominance index because it weights towards the abundance of the most common species. Simpson's Index gives the probability of any two individuals drawn at random from an infinitely large community belonging to different species.

$$D_S = \sum_{i=1}^{S} \frac{\left(n_i\left(n_i - 1\right)\right)}{\left(N\left(N-1\right)\right)} \quad 2)$$

where :

*n*i : the number of individuals in the *i*th species. Since *Ds* and diversity are negatively related, Simpson's index is usually expressed as either reciprocal or complementary forms (1/D or 1-*D*) so that as the index goes up, so does diversity.

**Evenness Index**

Evenness index is a measure of biodiversity which quantifies how equal the community is numerically.

$$J' = \frac{H'}{H'_{\max}} \quad 3$$

Where H' is the number derived from the Shannon diversity index and H' max is the maximum value of H', equal to:

$$H_{\max} = -\sum_{i=1}^{S} \frac{1}{S} \ln \frac{1}{S} = \ln S. \quad 4$$

Where:

S is total number of species

***E*** is constrained between 0 and 1. The less variation in communities between the species, the higher ***E*** is.

**Multi-Correlation Test (CCA test)**

Canonical Correspondence Analysis (CCA) has been developed to allow ecologists to relate the abundance of species to environmental variables (ter Braak, 1986). Mostly CCA was used to see the relationships between two groups of variables :

1. species variables versus environment variables (community ecology)
2. genetic variables versus environmental variables (population genetics)

In this research CCA was used to see the relationship between the landscape and land management type to the specific order of the insect.

## RESULTS AND DISCUSSION

**Insect Indicator Performance in Each Land-Use Type**

Monoculture agriculture has the largest number of Lepidoptera and Hemiptera family (herbivore insect dominated) while in agro-forest system has the largest number of Diptera and coleoptera family (scavenger insects dominated) (Figure 3). Further, mostly forest insect were captured in the night (nocturnal) while in rice-field they were active on the day (diurnal) (Figure 4).

From the analysis, in the protected forest and high disturbance landscape like highly pesticide land management, both showed the lower biodiversity richness. This phenomenon was likely due to in protected forest, there was a competitive exclusion followed by depletion of resources reduces the insect richness (high predation). On the other hand, in the high disturbed landscape, only few insect orders will be recover in the severe disturbance, hence also reduce the number of insect (low predation).

Biodiversity richness should be maximal at intermediate intensities of disturbance, such as Agro-forest landscape due to ability to adapt on the level of disturbance in their ecosystem through evolution mechanism.

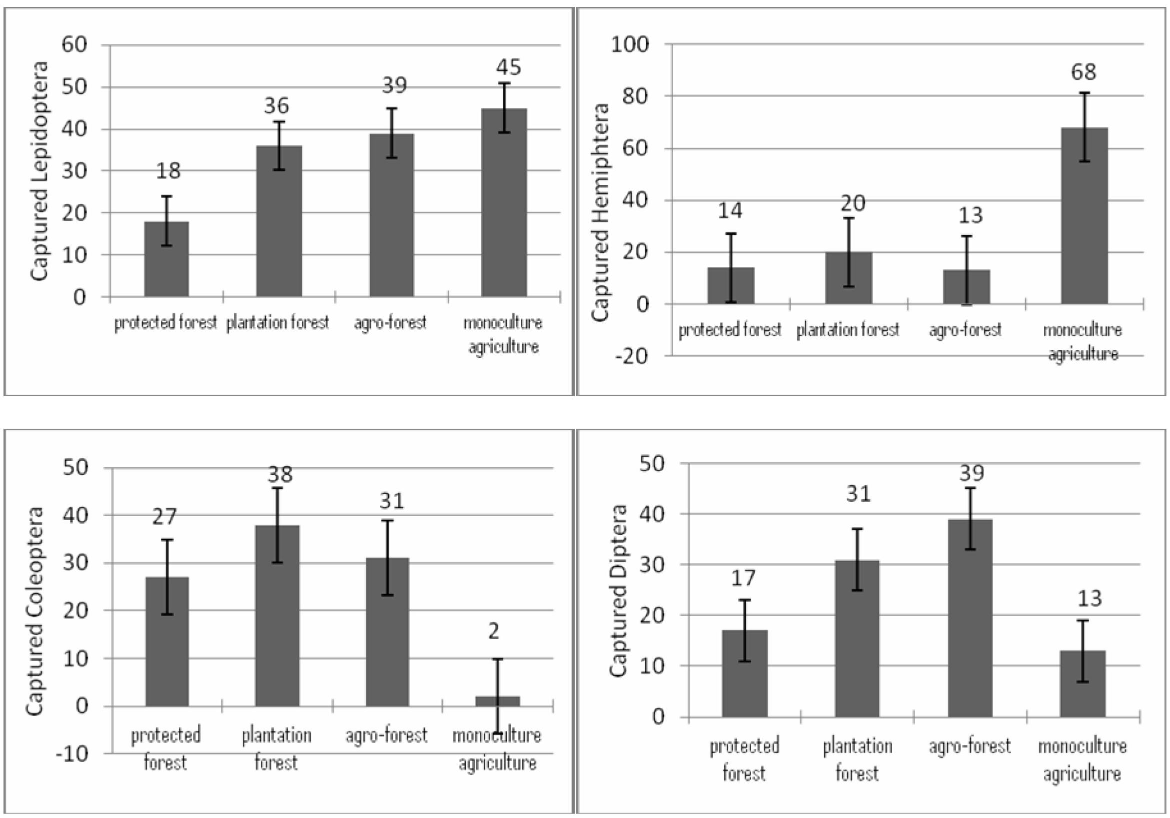



Figure 3. Daily average captured Insect

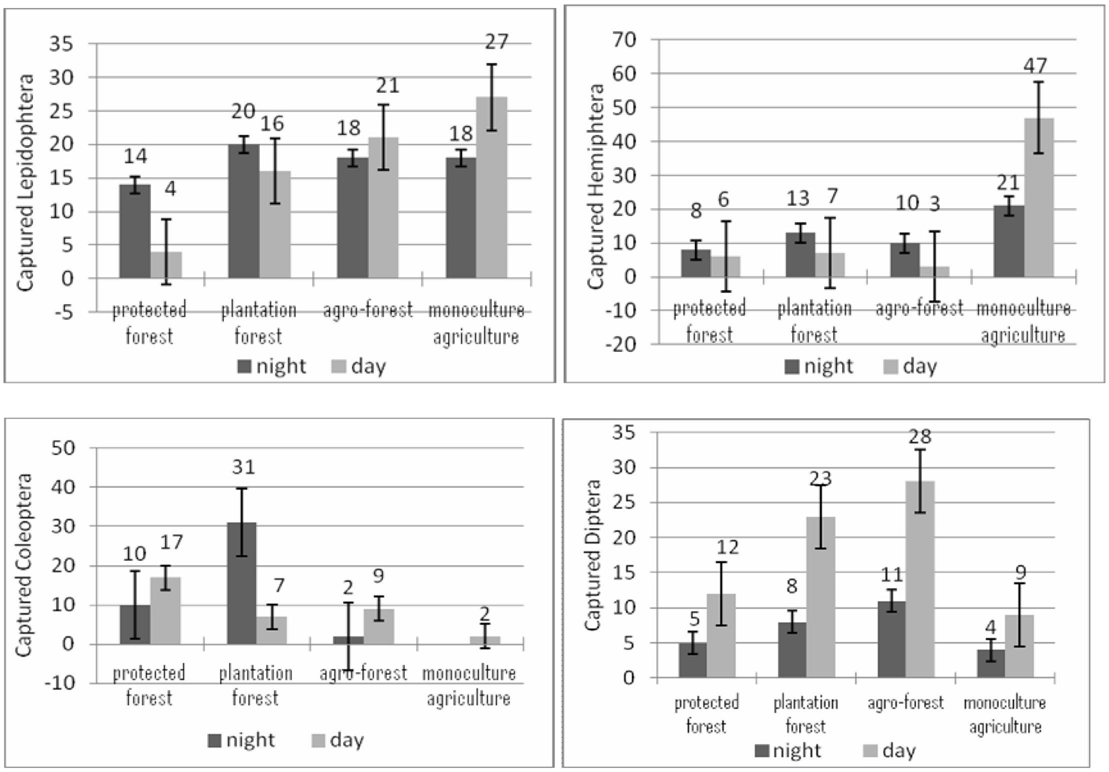



Figure 4. Captured Insect based on active time

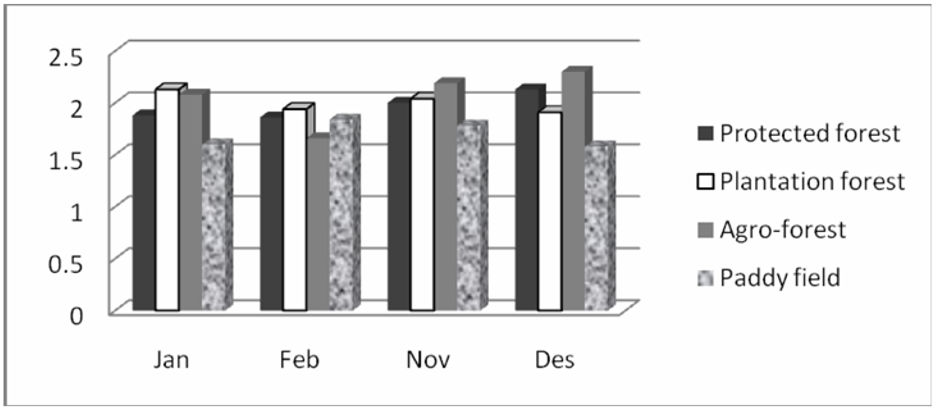
**Diversity, Dominance and Evenness Index**

After conducting the analysis on diversity, density and evenness index, it was found that both protected forest, plantation forest and agro-forest showed the similar index number which shows the similar ecological services for the insect as their habitat. However, in the monoculture agriculture, there was an unbalance insect composition and highest dominance number but low evenness index (Figure 5a, b and c).

Many researcher misunderstood that bio-indicator has their own specific function and purpose. In this research the bio-indicator was mainly studied for the differentiate landscape or land-use type, and does not have to the bio-indicator of "environmental health" which may not be linear correlate with biodiversity (Hellawell, 1986**;** Spellerberg, 199, Meffe and Carroll, 1994; Dufrene and Legendre, 1997)

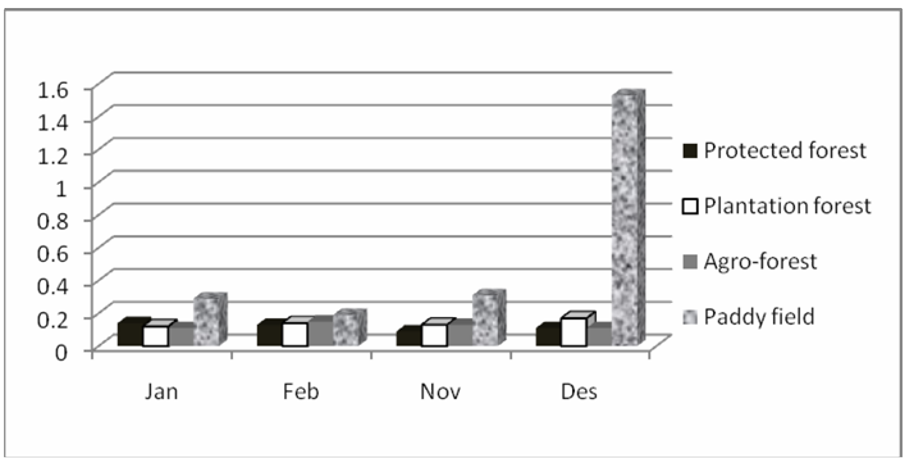
**Canonical Correspondence Analysis (CCA) and Intermediate Disturbance Hypothesis**

Using the CCA analysis with the CCA plot can be easily explain the distance or relationship between the Insect orders with the landscape / land management type. The axis represented the land-use type, from rice-field, protected forest, production forest and agro-forest, while the ordinate represented the pesticide application from no pesticide, medium pesticide to high pesticide application (the black box) while the white triangles were the distribution of each insect order in response of the landscape and pesticide application. From the graph it is clearly seen that rice-field and high pesticide application has the longest distance / relationship with the distribution of insect orders. On the other hand, agro-forestry and plantation forest (represented the medium disturbance environment) have a very close distance and relationship with most insect order distribution (Figure 6).



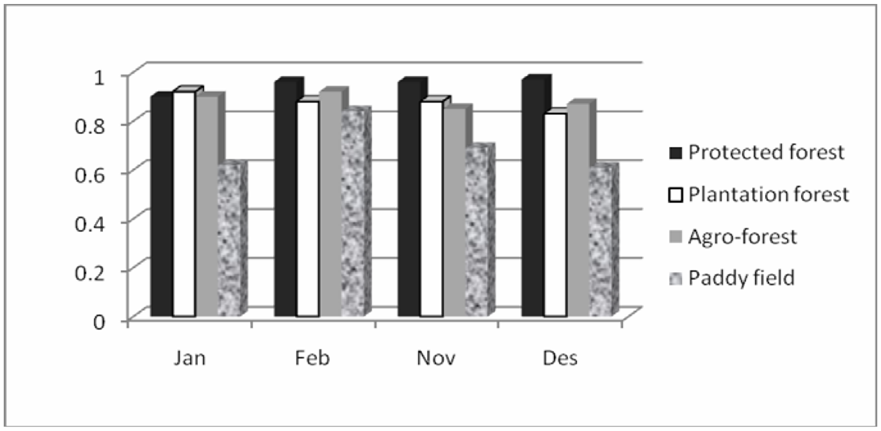

Notes: H' can range of 0 to 4.6 using natural log (ln). H value near 0 would indicate that every species in the sample is the same. H value near 4.6 would indicate that the number of individuals are evenly distributed between all the species.

Figure 5a. Shannon Wiener diversity index (H)




Notes: Dominance Index will decrease if diversity index is increase and the higher value, shows less diversity

Figure 5b. Simpson's index (dominance index)




Notes: Evenness Index ***E*** is a measure of biodiversity which quantifies how equal the community is numerically constrained between 0 and 1. The less variation in communities between the species, the lower ***E*** is.

Figure 5c. Evenness index range values 0 up to 1

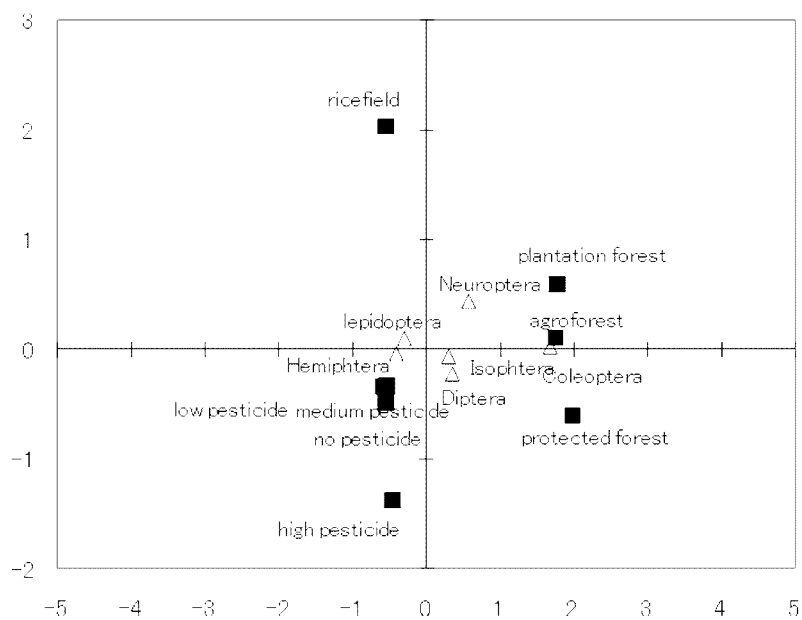



Figure 6. Multi-colinearity plot between insect order and land-use system

As discussed previously, the Intermediate Disturbance Hypothesis (IDH) or Medium Disturbance Hypothesis states that local species diversity is maximized when ecological disturbance is neither too rare nor too frequent (in between). At low levels of disturbance, more competitive organisms will push subordinate species to extinction and dominate the ecosystem (Grimme, 1973). Further Grimme (1979), Horn (1975) and Connell (1978) stated that at the high levels of disturbance, due to frequent forest fires or human impacts like deforestation and monoculture agriculture with high pesticide, all species are at risk of going extinct, except the new pest biotype. According to this hypothesis, intermediate levels of disturbance like agro-forestry or plantation forestry, diversity is maximized because both competitive organisms and species can coexist well. This coexistence is a result of the differing life history strategies of species, which dictate a preference for high or low disturbance.

Hence according to Connell (1978), selected species like the pest in the monoculture rice-field tend to be more competitive, because they invest a larger proportion of resources into growth and competition and thus generally dominate stable ecosystems over long time periods. In contrast, selected species, which colonize open areas quickly, can dominate landscapes recently cleared by disturbance like the case of pest resurgence. Therefore, in areas where disturbance occurs occasionally, both species can take advantage of the same region.

Based on multi-colinear corelation analysis it could be concluded that rice field and high pesticide land use systems, have the longest distance with the distribution of insect family, further agro-forest land use system has no different with plantation forest and protected forest in term of the relationship with insect distribution.

Traditional production landscapes in Wonogiri and other the sustainable practices namely Satoyama landscape are increasingly threatened in many parts of the world, due to urbanization, industrialization, and rural population increase and decrease.

Protected area is still needed to keep the biodiversity pole of the environment system, however managing and developing biodiversity not only preserving pristine environments, such as wilderness, but also conserving human-influenced natural environments, such as agro-forestry practices farmlands and secondary forest, that people have developed and maintained sustainably over a long time (Traditional landscape). This landscape type is also important because they have developed their own specific biodiversity system represented their own specific natural resources.

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