
**UNIVERSITI PUTRA MALAYSIA**

# *AN ECOLOGICAL STUDY OF TROPICAL BUTTERFLIES IN MONOCULTURE AND POLYCULTURE OIL PALM AGRO ECOSYSTEMS*

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# AN ECOLOGICAL STUDY OF TROPICAL BUTTERFLIES IN MONOCULTURE AND POLYCULTURE OIL PALM AGRO ECOSYSTEMS

By

**SITI ASMAH BINTI MUSLIM**

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Master Science**

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**August 2016**

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Commercial oil palm farming is growing rapidly and becoming common among small-scale farmers in the tropics. This is due to the global need of palm oil in various products and also, for providing sustainable income to farmers. However, land conversion into oil palm plantations and smallholdings has a major impact on biodiversity. In existing oil palm production landscapes, little is known on how farmland butterfly diversity is being affected by different farming practices. In this study, butterfly community under different farming practices in oil palm smallholdings, was investigated. To determine which farming practices supported more butterfly diversity, two different practices were assessed in this study. The first is the polyculture farming (mixed crop species including oil palm and banana) and the other being monoculture farming, which consists only oil palms crops. Polyculture smallholdings were predicted to be able to support greater butterfly biodiversity than monoculture smallholdings. Plant heterogeneity may increase niche diversity and appear as a host for a variety of butterflies. This study compared species richness and composition between monoculture and polyculture smallholdings. This study also determined habitat quality characteristics that are important for butterfly to maintain greater species richness. Butterflies were sampled using Van Someron–Rydon butterfly trap at 120 sites, where 60 sites were spatially replicated at monoculture and polyculture smallholdings. Contrary to initial prediction, our results showed there were no significant differences in species richness, abundance and composition of butterflies between the polyculture and monoculture smallholdings. The findings suggested that the adverse effects of monoculture farming on biodiversity can be mitigated in smallholding. This is by introducing structural and compositional habitat

heterogeneity through the practice of polyculture farming. Habitat quality explained 32.1% of the variations in butterfly richness. In conclusion, oil palm production landscapes should feature multiple farming practices such as those implemented in smallholdings for improved conservation of butterfly diversity.

Abstrak tesis dikemukan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

**KAJIAN EKOLOGI KUPU-KUPU TROPIKA DI MONOKULTUR DAN POLIKULTUR DALAM KAWASAN EKOSISTEM PERTANIAN KELAPA SAWIT**

Oleh

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Pertanian kelapa sawit komersial berkembang dengan pesat dan semakin popular berbanding pertanian yang berskala kecil yang lain di kawasan tropika. Ini adalah kerana, penghasilan pelbagai produk berasaskan kelapa sawit menghasilkan kadar pendapatan yang lebih stabil. Walau bagaimanapun, perubahan penggunaan tanah di ladang kelapa sawit dan pekebun kecil sedikit sebanyak memberi kesan terhadap biodiversiti persekitaran. Kewujudan hasil landskap yang berbeza di kawasan kelapa sawit, tidak ramai yang mengetahui kesan biodiversiti terhadap amalan jenis pertanian yang berbeza. Oleh yang demikian, komuniti kupu-kupu digunakan dalam kajian ini bagi membanding jenis amalan pertanian yang berbeza di kawasan ekosistem pertanian kelapa sawit, kajian ini dilakukan di kebun kecil. Bagi mengetahui jenis amalan pertanian manakah yang menyokong biodiversiti kupu-kupu, dua jenis pertanian yang berbeza digunakan dalam kajian ini iaitu pertanian polikultur (campuran spesies tanaman kelapa sawit dan pisang) dan pertanian monokultur dimana keseluruhan adalah spesies kelapa sawit. Kebun kecil jenis polikultur dijangkakan dapat menyumbang lebih banyak biodiversiti kupu-kupu berbanding kebun kecil jenis monokultur. Ini disebabkan oleh, ciri kepelbagaian spesies pokok mungkin akan meningkatkan kepelbagaian niche dan tumbuhan perumah kepada spesies kupu-kupu. Oleh yang demikian, kajian ini membandingkan komposisi dan kekayaan spesies kupu-kupu di antara dua jenis amalan pertanian, monokultur and polikultur di kebun kecil. Kajian ini juga dijalankan bagi menentukan ciri habitat kualiti yang wujud di kawasan tersebut di mana iamerupakan element penting untuk mengekalkan kekayaan spesies dan mungkin menampung biodversiti di kawasan tersebut. Kupu-

kupu berfungsi sebagai penunjuk dalam persampelan ini dengan menggunakan perangkap kupu-kupu di 120 kawasan, dengan 60 repliket spatial kawasan pada kedua-dua kawasan pertanian monocultur dan polikultur kebun kecil. Bertentangan dengan jangkaan awal, keputusan menunjukkan tiada perbezaan yang ketara kekayaan spesies, kelimpahan dan komposisi kupu-kupu di kedua-dua jenis amalan di kebun kecil, monokultur dan polikultur. Kesan buruk ke atas biodiversiti di kawasan monokultur sebenarnya dapat dikurangkan. Di mana dengan mengubah komposisi struktur dan kepelbagaian spesies melalui amalan pertanian polikultur. Kehadiran habitat kualiti menunjukkan 32.1% variasi dalam kepelbagaian spesies mampu menarik kupu-kupu di kawasan kelapa sawit kebun kecil. Kesimpulannya, hasil landskap kelapa sawit perlu mempunyai ciri yang pelbagai seperti yang dilaksanakan di kebun kecil bagi memelihara kepelbagaian kupu-kupu.

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I certify that a Thesis Examination Committee has met on 22 August 2016 to conduct the final examination of Siti Asmah binti Muslim on her thesis entitled "An Ecological Study of Tropical Butterflies in Monoculture and Polyculture Oil Palm Agro Ecosystems" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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| | |
|---|---|
| % | Percent |
| - | Negative |
| ± | Plus minus |
| $^{o}$C | Degree Celsius |
| m | Meter |
| X | Multiplied |
| = | Equal |
| \|r\| | No element of set r |
| ACE | Abundance Coverage-based Estimator |
| AIC | Akaike's Information Criterion |
| AICc | Akaike's Information Criterion Correction |
| ANOSIM | Analysis of Similarity |
| ANOVA | Analysis of Variance |
| F | F- statistic |
| GLM | Generalized Linear Modals |
| I△ | Delta I |
| MPOB | Malaysia Palm Oil Board |
| MPOC | Malaysian Palm Oil Council |
| NMDS | Non-metric Multi Dimensional Scaling |
| p | p- value |
| $R^2$ | R squared |
| S.E. | Standard Error |
| SIMPER | Similarity Percentage |
| Sp. | Species (singular) |
| Spp. | Species (plural) |

# CHAPTER 1

# INTRODUCTION

## 1.1 General Review

The high global demand for oil palm products, especially in food and biofuel industries, has led oil palm (*Elaeis guineensis*) plantation to expand in the last five decades (Corley & Tinker, 2008; Koh & Ghazoul, 2008). In Malaysia and Indonesia, more than 14.5 million hectares of land area was planted with oil palm (Foster *et al.,* 2011). In Peninsular Malaysia, 5.2 million hectares areas were planted with oil palms in 2012 (MPOB, 2013) and the rate of expansion might increase in the next few years. However, the expansion and intensification of management in oil palm plantations are threats to biodiversity (Fitzherbert *et al*., 2008; Sachs *et al*., 2009; Fayle *et al.,* 2010; Foster *et al*., 2011) and may lead to species extinction (Gibbs *et al*., 2010). This is particularly true in Malaysia which has among the highest number of endangered species globally (Carter *et al*., 2007; Turner *et al*., 2008). However, oil palm plantations can be properly managed to enhance their value for biodiversity (Fitzherbert *et al.,* 2008; Azhar *et al*., 2011, 2013). Previous studies have shown that oil palm plantations provide shelter for certain wildlife species (Koh, 2008; Nájera & Simonetti, 2010a; Azlan & Sharma, 2006). Oil palm plantations also have been found to support various groups of arthropods such as bees (Liow *et al.,* 2001), dung beetles (Davis & Philips, 2005) and woodlice (Hassall *et al*., 2006). However, most previous studies have not taken into account the influence of oil palm management practices on biodiversity. By incorporating the farming practices in conservation strategy, the farmland biodiversity in oil palm production landscapes can be enhanced.

## 1.2 Agricultural for Biodiversity

Agricultural practices such as monoculture and polyculture farming may impact many different ecological aspects of the farmland habitat (Benton *et al*., 2003; Holzschuh *et al*., 2007; Rundlöf *et al*., 2008; Azhar *et al*., 2014a; Savilaakso *et al*., 2014). Habitat heterogeneity, whether measured at small scale level or large scale level, is associated with higher biodiversity in agricultural landscape (Benton *et al*., 2003). Animal species diversity is driven by habitat heterogeneity (Tews *et al*., 2004), that is inextricably linked with vegetation structural complexity and floristic diversity. The development of structural complexity and floristic diversity may provide additional vegetation components in agricultural landscape (Cunningham *et al.,* 2008) that improve faunal diversity (Munro *et al*., 2009).

Similarly, both structural complexity and floristic diversity are important for maintaining biodiversity in oil palm production landscapes (Nájera & Simonetti, 2010a, 2010b). However, this is more typical for oil palm smallholdings rather than conventional plantations. Unlike large-scale and even-aged monoculture oil palm plantations, polyculture smallholdings provide structural and functional stability (Igbozurike, 1978) for biodiversity, creating through multiple agricultural practices (Azhar *et al*., 2013, 2014b). At a landscape scale, the combination of polyculture and monoculture farming in smallholdings may increase habitat heterogeneity. This is by making the smallholding a high quality matrix in improving species movement between habitat patches (Azhar *et al*., 2015). This includes the movement of insect species such as butterflies that inhabit oil palm environment.

### 1.3 Problem Statement

Forest conversion into oil palm plantations are increasing at an unsustainable rate, making it one of Malaysia's highest profitable industry (Fitzherbert *et al.,* 2008). Clearing forests for the sole purpose of oil palm plantation is very worrisome (Sodhi *et al*., 2010). The expansion of oil palm plantations also threatens biodiversity (Tilman *et al.,* 2001; Donald *et al.,* 2004; Green *et al*., 2005) and poses a serious threat to natural ecosystem worldwide. At the same time, expansion of oil palm plantations needs to be controlled and managed well to prevent species extinction or at this rate, we will lose all our breathtaking natural resources.

To date, almost 55% forest areas have been cleared in Malaysia and Indonesia to be replaced with oil palm plantations (Koh & Wilcove, 2008; Vargas, 2015). Vast clearings and forest conversion resulted in destruction of wildlife habitat and if it is not halted, future efforts will be in vain. In order to save remaining forest habitats and strengthen wildlife protection, selection of initiatives need to be drastic and decisions involving environmental policies must be evaluated before implementation. For an instance, oil palm plantation must be wildlife friendly as in it must be capable for duplicating a pseudo habitat for the wildlife.

Oil palm plantation can be categorized into monoculture farming which emphasizes single species and polyculture farming is the practice of culturing more than one species. Correa *et al.,* 2006 stated that polyculture farming may increase presence of wildlife species due to heterogeneous food sources. It is assumed polyculture farming practices is more suitable to be converted into wildlife protection area. To investigate the suitability of an area, scientific researches need to be carried out on both type of farming smallholdings to be converted into wildlife protection area, using butterflies as biological indicator.

## 1.4 Justification

The research may provide a solution for decision-making on biodiversity degradation due to growing of agricultural landscapes in palm oil producing countries. Loss of biodiversity from tropical deforestation (Daily, 2001; Lindermayer & Hobbs, 2004; Brook *et al*., 2006) and forest conversion into oil palm plantation are hard to mitigate. This is due to the high profitability and revenue this industry is able to generate (Smith *et al*., 2003; Sodhi & Brook, 2006; Koh & Wilcove, 2007). Therefore, this study was conducted as an initiative to preserve and enhance the biodiversity in the oil palm plantation.

Butterfly surveys were conducted in habitats that have been transformed into oil palm smallholdings (e.g. monocultures and polyculture farming practice), with the aim to compare butterfly diversity in different farming practices. This study predicted that polyculture smallholdings would support higher level of butterfly richness and more diverse species assemblages than monoculture smallholdings. This was attributed to greater structural complexity and floristic richness in polyculture smallholdings. The second objective is to study the relationships between butterfly species richness and local-scale habitat quality characteristics (i.e. vegetation structure). This study predicted that key structural characteristics typically associated with agricultural practices play an important role in influencing butterfly species richness and composition. Indeed, these help ecologists to understand biodiversity patterns in modern human-modified environments and at the same time give recommendations to conserving the biodiversity especially butterflies in farmland areas.

## 1.5 Objective

The study aimed to investigate how farmland diversity was associated with the agricultural practices of existing oil palm production landscapes. Butterfly was used as indicator because it is the best taxon for various ecological studies (Sparrow *et al*., 1994; Miller *et al*., 2011). Therefore, this study focused on butterfly species diversity in different farming practice (monoculture and polyculture system) in Malaysia. The specific objectives were:

i. To compare butterfly diversity, abundance and assemblage composition between polyculture and monoculture smallholdings.
ii. To examine the relationship between butterfly species richness and habitat quality.

## 1.6 Research Hypothesis

**i.** Polyculture smallholdings are characterized by high value of species richness, whereas monoculture smallholdings are characterized by low value of species richness.

**ii.** Some vegetation structure attributes for example, percentage of ground vegetation cover are the main drivers of species richness.

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