UNIVERSITI PUTRA MALAYSIA

DIVERSITY OF ARTHROPOD SOIL DWELLER IN RELATION TO MONOCULTURE AND POLYCULTURE PRACTICES IN OIL PALM SMALLHOLDINGS IN SELANGOR, MALAYSIA

AMAL GHAZALI BIN NASRON

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By

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

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Abstract of the thesis presented to the Senate of Universiti Putra Malaysia
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Oil palm plantation has become one of the economic mainstays for biodiversity-rich countries in the tropics. It plays a major role in the economy of Malaysia as the second largest producer of palm oil and oil palm related products after Indonesia. The conversion of native forests to oil palm monoculture system has caused biodiversity loss. With proper planning and implementation of farming practice, oil palm agriculture in Malaysia can go further as an economic backbone. However, little is known about the effects of oil palm polyculture system on biodiversity. Studying arthropod diversity in response to different habitat variables will give evidence to support wildlife conservation in the expanding oil palm industry. The smallholdings were chosen as representatives of the oil palm smallholdings in Peninsular Malaysia as they include both oil palm and banana plants. In this study, arthropods are used as ecological indicators while pitfall traps were used in data collection. Systematic sampling of insects with random starting points were used in pitfall trapping in each plot. Arthropod diversity was examined with respect to abundance, number of orders (order richness) and community composition responded to different farming practices and vegetation structure characteristics. Across oil palm smallholdings, the number of arthropod orders were significantly higher in polyculture smallholdings than monoculture smallholdings. However, there were no significant difference in arthropod abundances in both monoculture and polyculture smallholdings. Habitat quality variables explained 15.98% of arthropods richness. The most significant predictor variables in influencing arthropod diversity were polyculture farming practice, height of oil palm crop and number of immature oil palm. This study concluded that polyculture smallholdings can host a wider arthropod order than monoculture smallholdings. Arthropods were shown to favour multiple crops that offer variety of food sources for different trophic levels. The findings of this study suggest that, in order to preserve biodiversity, oil palm stakeholders should maintain as much of the remaining arthropod biodiversity as possible by sustaining local habitat complexity in the smallholdings. This practice is not only

important for the oil palm smallholding sustainability, but it also increases arthropods richness that helps to carry out important ecological niche and functions in the oil palm landscape such as floral pollination, pest predation, decomposing of litter layer and recycling of nutrient cycle.

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KEPELBAGAIAN ARTROPODA PENGHUNI TANAH BERHUBUNG DENGAN AMALAN MONOKULTUR DAN POLIKULTUR DALAM KEBUN KECIL KELAPA SAWIT DI SELANGOR, MALAYSIA

Oleh

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Pertanian sawit telah menjadi salah satu daripada tulang belakang ekonomi bagi negara-negara yang kaya dengan biodiversiti di kawasan tropika. Pertanian sawit memainkan peranan penting dalam ekonomi Malaysia sebagai pengeluar kedua terbesar produk berkaitan kelapa sawit dan minyak kelapa sawit, selepas Indonesia. Penukaran hutan asli untuk sistem monokultur kelapa sawit telah menyebabkan kehilangan biodiversiti. Dengan perancangan dan pelaksanaan amalan pertanian yang betul , pertanian kelapa sawit di Malaysia boleh pergi lebih jauh sebagai tulang belakang ekonomi negara. Walau bagaimanapun, sedikit yang diketahui tentang kesan-kesan sistem polikultur kelapa sawit terhadap biodiversiti. Mengkaji kepelbagaian artropoda sebagai tindak balas kepada pemboleh ubah habitat yang berbeza akan memberikan bukti untuk menyokong pemuliharaan hidupan liar dalam industri kelapa sawit yang semakin berkembang. Kebun kecil sawit telah dipilih untuk mewakili kebun kecil kelapa sawit di Semenanjung Malaysia kerana termasuk kedua-dua kelapa sawit dan pokok pisang. Dalam kajian ini, artropoda digunakan sebagai indikator ekologi manakala perangkap 'pitfall' telah digunakan dalam pengumpulan data. Persampelan sistematik serangga dengan titik permulaan rawak telah digunakan dalam memerangkap perangkap dalam setiap plot. Kajian ini mengkaji kesan tindak balas diversiti artropoda berkenaan dengan kelimpahan, bilangan order dan komposisi komuniti kepada amalan pertanian yang berbeza dan ciri-ciri struktur tumbuh-tumbuhan. Di seluruh kebun kecil kelapa sawit, bilangan order artropoda adalah jauh lebih tinggi dalam kebun kecil polikultur daripada kebun kecil monokultur. Walau bagaimanapun, tidak terdapat perbezaan yang signifikasi dalam kelimpahan artropoda dalam kedua-dua kebun kecil monokultur dan polikultur. Pembolehubah kualiti habitat menjelaskan 15.98% daripada bilangan artropoda. Pembolehubah peramal yang paling penting dalam mempengaruhi biodiversiti artropoda ialah amalan pertanian polikultur, ketinggian tanaman kelapa sawit dan bilangan pokok sawit tidak matang. Kajian ini memberi kesimpulan bahawa kebun kecil polikultur

boleh menjadi perumah bagi artropoda yang lebih berkesan daripada kebun kecil monokultur. Artropoda memihak kepada pelbagai tanaman yang menawarkan pelbagai sumber makanan untuk peringkat trofik yang berbeza. Hasil kajian ini menunjukkan bahawa, bagi memelihara biodiversiti, pekebun kecil kelapa sawit perlu mengekalkan sebanyak mungkin biodiversiti artropoda dengan mengekalkan kepelbagaian habitat tempatan dalam kebun mereka. Amalan ini bukan sahaja penting untuk kemampanan kebun kecil kelapa sawit, tetapi juga meningkatkan kekayaan artropod yang membantu untuk menjalankan niche dan fungsi ekologi yang penting dalam landskap kelapa sawit seperti pendebungaan bunga, perosak pemangsa , menguraikan lapisan sampah dan kitar semula nutrien.

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This thesis submitted to the Senate of Universiti Putra Malaysia has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisor Committee are as follows:

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This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision ;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

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LIST OF ABBREVIATIONS AND SYMBOLS

%	Percentage
&	And
Δi	Delta i
AIC	Akaike's Information Criterion
AICc	AIC correction
ANOSIM	Analysis of Similarity
ANOVA	Analysis of Variance
AOCS	American Oil Chemists Society
CC	Percentage of canopy cover
Chi Pr	Chi probability
cm	Centimetre
DF	Degrees of freedom
DOPS	Number of dead oil palm (standing)
E	East
PE	Percentage of epiphyte
F	*F*-value for ratio of mean square
g	Gram
GC	Percentage of grass cover
GLMs	Generalized Linear Models
Global R	Sample statistic for Global Test
GNI	Malaysia's Gross National Income
ha	Hectare
HG	Height of grass cover
HNG	Height of non-grass cover
HOPC	Height of oil palm crop
IT	Information Theory
ITTO	The International Tropic Timber Organisations
L	Litre
L.E.D	Light emitting diode
lrl	R modules
m	Meter

mL	Millilitre
mm	Millimetre
N	North
NGC	Percentage of non-grass cover
NMDS	Non-Metric Multidimensional Scaling
OPI	Number of immature oil palm crop
p	P-value of Test
Pr> F	Significance probability associated with the *F* statistic
r	R-value of test
R^2	Goodness of Fit (0.0-1.0)
RM	Ringgit Malaysia
S.E.	Standard error
SIMPER	Similarity Percentage
TYP	Type of farming practice
VSN	Veresen Inc
WWF	World Wildlife Fund

CHAPTER 1

INTRODUCTION

1.1 General Review

Arthropods have long been considered as an integral part of biodiversity as it provide immense ecological functions and represent more than 80% of total faunal species diversity (Dial *et al*., 2006; Basset, 2001; Wilson 1992). Arthropods, microbes, and other small organisms maintain stability of various ecosystems including tropical forests, temperate woodlands, urban parks and agricultural farmlands (Pimentel *et al*., 1992). As part of their ecological functions, majority of arthropods can act as natural enemies that provide biological control of insect pests (Letourneau *et al*., 2009). They are also essential to the survival of many plant species as insects serve a major role in pollination (Delaplane *et al*., 2000; Braack, 1997; Bawa, 1990).

Studies showed that insect pollinators such as bees, butterflies, and ants act as important pollinators for flowering plants in rainforests as well as farmlands such as oil palm plantations (Ramirez *et al*., 2010; Klein *et al*., 2007; Thiele, 2005). Pollinating insects are an important constituent of biodiversity (Kevan, 1999). Recent research in oil palm plantations studied insects such as ants (Fayley *et al*., 2012; Yusah *et al*., 2012; Klimes *et al*., 2012), butterflies (Barlow *et al*., 2007; Fitzherbert *et al*., 2006; Hamer *et al*., 2005), orchid bees (Livingston *et al*., 2013) and other arthropods (Dial *et al*., 2006; Wettstein & Schmid, 1999) in order to investigate the detrimental effects of deforestation for agricultural expansion.

1.2 Status of Malaysian Palm Oil

Conversion of natural ecosystems into agricultural lands has become a major threat to global biodiversity due to poor environmentally friendly practice (Ewers *et al*., 2009). Over the past few decades, oil palm (*Elaeis guineensis Jacq.*) has become one of the most rapidly expanding equatorial crops in the world (Clay, 2004; Koh & Wilcove, 2007). Vast areas of forests have been converted to commercial oil palm plantations due to the significant contribution on the economy of the producing countries (Koh, 2008; Koh & Wilcove, 2007). This is particularly true in Malaysia as the country currently accounts 39% of world palm oil production and 44% of world exports (MPOC, 2014). In the state of Sabah in eastern Malaysia, the decrease in forest cover has been chiefly due to the development of agricultural areas. Consequently, this leads to an area of over 800,000 ha being planted with oil palm (McMorrow & Talip, 2001). Thus, the large scale expansion of oil palm plantations raises question on how the management practices in the plantations can contribute in biodiversity conservation.

1.3 Biodiversity Degradation of Forest in Malaysia

Protecting forest biodiversity from deforestation caused by oil palm expansion is a primary concern among conservationists (Ewers *et al*., 2009; Dhaliwal *et al*., 2007; Casson, 2003). However, maintaining farmland biodiversity is equally important in existing oil palm-dominated landscapes (Koh & Wilcove, 2007; Fayle *et al*., 2010). The key value of biodiversity is that their individual attributes and interactions help in maintaining and stabilizing ecosystem functions (Loreau *et al*., 2001; Hooper *et al*., 2005). Previous studies have shown that oil palm plantation has the ability to maintain faunal biodiversity (Azhar *et al*., 2014). This is due to polyculture farming practice in oil palm smallholdings which are planted with multiple crops such as cocoa, coffee, banana and coconut that provide shelter and foraging grounds for some animal species (Kim *et al*., 2006; Nair, 2007; Foster *et al*., 2011).

Faunal diversity has been found to be correlated with plant diversity (Weibull *et al*., 2003). In agroecosystem and forestry management, increasing plant diversity has been linked to the increase in insect diversity (Hamer *et al*., 2005; Haddad *et al*., 2001; Dennis *et al*., 1998). Lower insect herbivory damage was found to be caused by an increase in interspecific competition among pest and non-pest species, and improved natural enemy communities (Cardinal *et al*., 2006). Recent research has suggested that oil palm plantations serve as a potential host for arthropods from nearby disturbed or destroyed forests of Sabah, Malaysian Borneo (Lucey & Hill, 2012). As such, there is a great need to quantify biodiversity in oil palm landscapes in order to reconcile palm oil production and biodiversity conservation. Although there were studies regarding biodiversity conservation in large-scale oil palm plantations (Khairiyah *et al*., 2013; Lucey & Hill, 2012; Edwards *et al*., 2010; Koh, 2008), similar studies (Azhar *et al*., 2014*a*, Azhar *et al*., 2014*b*; Azhar *et al*., 2013; Azahr *et al*., 2011) in oil palm smallholdings are limited in which management practices are different from those of plantations.

1.4 Problem Statements

One question that needs to be asked is whether farmlands can provide a refuge for wildlife such as arthropods? Based on a recent study by Turner and Foster (2009), arthropods experienced different levels of declination with some groups having higher abundance in oil palm plantations compared to primary forests and logged forests in Sabah. Several studies revealed that ant abundance in polyculture oil palm practice was found to be similar to that in natural forest in the Caribbean forest landscape (Donald, 2006; Glor *et al*., 2001), but was lowest in monoculture oil palm farming practice in Papua New Guinea (Room, 1975).

Although species richness of forest ants decreased with the expansion of agricultural plantation, Bruhl and Eltz (2010) found evidence that showed nine species of ants that had never been observed in forest were found in oil palm plantations. This implies a community shift of ants towards non-forest species of Sabah in agricultural plantation (Bruhl & Eltz, 2010). Polyculture farming practice provides important ecosystem goods and services including maintaining habitats for pollinators and beneficial insects (Thrupp, 2000) when compared to monoculture farming practice. However, to what extend does habitat complexity effects terrestrial arthropods diversity?

This study intended to answer three research questions with respect to biodiversity pattern of terrestrial arthropods in oil palm smallholdings; (1) how terrestrial arthropods respond to polyculture and monoculture practices? (2) to what extent does the habitat quality attributes influence the number of arthropod orders and their abundance in oil palm smallholdings? and (3) how polyculture and monoculture farming practices influence arthropod composition in oil palm smallholdings?

1.5 Hypothesis

In this study, there are three main hypothesis that are related to the outcome of arthropod diversity with respect to different farming practices. (1) it is predicted that the abundance of arthropod was higher in monoculture smallholdings than polyculture smallholdings because it may only attract some species of arthropods that can dominate the smallholdings. However, arthropod order richness was higher in polyculture smallholdings than monoculture smallholdings because of the variation of habitat quality parameters in both farming practices (Knops *et al*., 1999; Landis *et al*., 2005; Kim & Kremen, 2006; Khairiyah *et al*., 2013). (2) it is predicted that local habitat quality attributes may explain the variation in arthropod abundance and richness between monoculture and polyculture farming practices (Dennis *et al*., 1998; Haddad *et al*., 2001; Fayle *et al*., 2010). (3) it is predicted that arthropod composition was more diverse in polyculture smallholdings than monoculture smallholdings (Dunn & Gotelli, 2004; Lucey & Hill, 2012; Luke *et al*., 2014).

1.6 Justification

Based on previous studies, arthropods were used as an ecological indicators as they are highly sensitive to the changes in ecosystem surrounding them including their adapted habitat (Letourneau *et al*., 2009; Maleque *et al*., 2009; Oliver *et al*., 1999). They are beneficial to the environment as they improve the ecosystem by ensuring the continuation of natural processes such as flora pollination, prey-predator process of natural enemies for pest and improve the soil structure, among other vital processes. Studying arthropod diversity in response to different habitat variables will give evidence to support wildlife conservation in the expanding oil palm industry. This study also took into account different farming practices in these smallholdings, namely monoculture and polyculture farming in an attempt to determine farming practices that support a higher level of arthropod diversity.

1.7 Objectives

The main objective of this study was to determine the effects of habitat complexity between polyculture and monoculture farming practice with respect to pattern of terrestrial arthropods in oil palm smallholdings.

The specific objectives of the study were:

a) To compare terrestrial arthropods diversity between polyculture & monoculture smallholdings; and
b) To determine the key habitat quality variables that influence arthropod abundance and richness in oil palm smallholdings.

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LIST OF PUBLICATIONS

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