Effects of monoculture and polyculture farming in oil palm smallholdings on terrestrial arthropod diversity

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Abstract

Oil palm agriculture has become one of the economic mainstays for biodiversity-rich countries in the tropics. The conversion of native forests to oil palm monoculture plantation has caused unprecedented biodiversity loss in Southeast Asia. Little is known about the effects of oil palm polyculture farming on arthropod diversity. In this study, arthropods were sampled using pitfall traps at 120 sites in Peninsular Malaysia. We examined how arthropod biodiversity responded to different oil palm farming practices and local-scale vegetation structure characteristics. We found that the number of arthropod orders was significantly greater in polyculture than monoculture smallholdings. However, we did not detect a significant difference in arthropod order composition nor abundance between monoculture and polyculture practices. *In situ* habitat characteristics explained 16% of the variation in arthropod order richness, with key predictor variables including farming practice, height of oil palm stands, and number of immature palms. The findings of this study suggest that polyculture farming together with management for *in situ* habitat complexity may be a useful strategy in supporting biodiversity within in oil palm plantations.

Keywords

Arthropods; Diversity; Habitat characteristics; Farming practice; Oil palm smallholdings

Introduction

Arthropods including insects, are the most numerous phylum on Earth and represent more than 80% of global species richness (Wilson, 1992). They are also responsible for a wide range of important ecosystem functions, including biological control of pests (Letourneau et al., 2009) and pollination, both in natural habitats and in agricultural landscapes (Thiele, 2005; Klein et al., 2007; Ramirez et al., 2010). In agro-ecosystems, these arthropods also aid in decomposition of organic matter in soil (Ahmad & Ahmad, 2009) and at the same time are food source for their natural predators (Greenberg et al., 2000). However, intensively managed agriculture (e.g. monoculture oil palm plantations) could significantly reduce arthropod biodiversity in comparison to the native forests (Bruhl & Eltz, 2010; Luke et al., 2014).

Conversion of natural forests into agricultural lands is currently one of the major threats to global biodiversity (Ewers et al., 2009) and represents a major conservation challenge. Over the past few decades, oil palm (*Elaeis guineensis* Jacq.) has become one of the most rapidly expanding tropical crops in the world (Clay, 2004; Koh & Wilcove, 2007). Vast areas of natural forests have been converted to commercial plantations, and the crop makes a substantial contribution to the economy of producing countries (Koh & Wilcove, 2007). This is particularly true in Malaysia, with the country currently producing 39% of the world’s palm oil production and 44% of world’s export (MPOC, 2014). Within Malaysia, the State of Sabah contains the biggest oil palm plantation area, accounting for around 29% of total oil palm plantation area in Malaysia (MPOB, 2015).

The large scale expansion of oil palm monoculture plantations has raised concerns about the impacts of oil palm expansion on biodiversity. Thus, it has reduced species richness and abundance in terms of biodiversity (Fitzherbert et al., 2008; Danielsen et al., 2009; Foster et al., 2011). For example, compared to forest, oil palm plantations have been found to contain a lower species richness of butterfly and birds (Koh & Wilcove, 2008) and ground-dwelling ants (Fayle et al., 2010). Protecting forest biodiversity from the ecological impact of oil palm expansion is a primary concern. However, maintaining farmland biodiversity in existing oil palm production landscapes is also important (Koh & Wilcove, 2007; Fayle et al., 2010). Previous studies have shown that oil palm can still host common or open-area species (Koh, 2008; Azhar et al., 2011, 2015). Oil palm production landscapes can also be habitats for a small number of forest species, given that oil palm farms are planted with other crops that provide shelter and foraging grounds for other wildlife (Kim et al., 2006; Nair, 2007; Foster et al., 2011). Polyculture farming is a common practise and considered to be ecologically more complex than monoculture farming (Rice, 2000; Altieri & Nicholls, 2004; Harvey et al., 2006). This has led to a focus on multi-cropping systems as a possible means of conserving farmland biodiversity (Dietsch et al., 2007; Steffan-Dewenter et al., 2007; Tylianakis et al., 2007). The planting of multiple crop species in commercial plantations has been found to have positive effects on insect diversity (Chung et al., 2000; Jones et al., 2003). For instance, studies have found that polyculture farming systems that integrate two or more crop species contain higher animal biodiversity compared to monoculture systems (Perfecto et al., 1996; Siebert, 2002).

Faunal diversity is often associated with plant diversity (Weibull et al., 2003). In agroecosystems, increasing plant diversity has been linked to an increase in insect diversity. Increased diversity can also result in lower insect herbivory damage, perhaps due to an increase in interspecific competition among pest and non-pest species, and a higher number of natural enemies (Cardinale et al., 2006). Oil palm plantations adjacent to forest can serve as a complementary habitat for arthropods originating from nearby disturbed forest (Lucey & Hill, 2012). Although many biodiversity studies have been carried out in oil palm landscapes, these have been mostly limited to large-scale monoculture plantations, where management practices are different from oil palm smallholdings. In addition, smallholdings are characterized by greater landscape heterogeneity than large-scale plantations (Azhar et al., 2015).

One of the key questions in tropical agricultural research is whether farmlands can provide a refuge for tropical biodiversity, including arthropods. (Turner & Foster, 2009), reported that different arthropod groups experience differing levels of decline between forest and oil palm plantation, with some groups having higher abundance in oil palm plantations compared to primary forests and logged forests in Sabah. In addition, although many species decline in oil palm plantations, some disturbance-tolerant species may also increase in abundance. For instance, a study from Papua New Guinea found that ant abundance and species richness was lower in monoculture oil palm compared to forest (Room, 1975), but that nine species of ants that had never been recorded in natural forest were found in oil palm plantations. Generally there therefore seems to be a community shift of ants towards non-forest taxa in oil palm plantations (Bruhl & Etlz, 2010).

To reconcile palm oil production and biodiversity conservation, it is important to understand factors that determine biodiversity patterns in oil palm production landscapes. Therefore, this study aimed to answer three research questions with respect to the pattern of terrestrial arthropod biodiversity associated with agricultural practices in oil palm smallholdings: (1) How does terrestrial arthropod abundance and richness differ between polyculture and monoculture oil palm smallholdings? (2) To what extent do *in situ* or local-scale habitat characteristics influence the arthropod abundance and order richness in oil palm smallholdings? (3) How does arthropod composition differ between polyculture and monoculture oil palm smallholdings?

Methods

Study area

The study was conducted at Banting (centred 02'47.804'N, 101'31.420'E; area = 5,244.82 ha), Tanjung Karang (centred 03'21.511'N, 101'13.163'E; area = 3993.88 ha) and Sabak Bernam (centred 03'48'09.1'N, 100'53'21.2'E; area = 5,479.49 ha), in the state of Selangor on the west coast of Peninsular Malaysia (Fig. 1). All locations were below 10 m above sea level. All sites were located on coastal areas that were characterized by peat soil and flat terrain. The size of smallholdings in the study areas were less than 5 ha each and managed by local farmers or independent smallholders. We assigned each smallholding to a category of polyculture or monoculture farming system, based on the crop species planted by the smallholders. Monoculture smallholdings were those exclusively planted with oil palm, while polyculture smallholdings were planted with oil palm, bananas and other crop plants (e.g. coconut and cassava).

Sampling design

We used systematic sampling with random starting points (Morrison, 2008). Sampling points were distanced at least 500 m apart. Data were collected from the three locations (i.e. Banting, Tanjung Karang and Sabak Bernam) where each had 40 sampling points. These points were allocated equally into monoculture (n = 20 sampling points) and polyculture smallholdings (n = 20 sampling points). Arthropod sampling was conducted from January to August 2014, using pitfall traps. Pitfall traps consisted of open plastic containers (473 ml, with diameter of 9 cm) sunk into the ground, with the rim of each container level with the ground surface and covered with a lid to prevent flooding and disturbance (Southwood, 1994). We poured a water and detergent mix into the traps to kill any insects that fell in (Lemieux, 1999), with added salt to act as preservative for collected specimens. The fluid was filled up to 2 cm from the base of the cup.

A total of 15 pitfall traps were used at each site, with a total of 1,800 pitfall traps used throughout the study period. Each pitfall trap was placed randomly within a 5-10 m radius from the other traps and at least 5 m from the edge of the smallholdings. Pitfall traps were left for three days at each site, which should be sufficient time to provide a reasonably good estimate of total arthropod richness and abundance (Olson, 1991). The arthropods were stored in 75% alcohol and identified to order in the laboratory (Capinera, 2010; Walters, 2011).

In situ habitat structure measurements

Thirteen habitat characteristics were assessed in 100 m x 100 m vegetation plots at each arthropod sampling point (Table 1). The percentage of understory vegetation cover of grass (i) and non-grass (ii) was measured at subpoints to the North, South, East and West (each plot 20 m apart). Mean height of the understory vegetation along the harvesting path was measured at subpoints to the North, South, East and West. This included (iii) height of grass cover and (iv) height of non-grass cover. Percentage canopy cover along the harvesting path was estimated using a canopy densiometer at subpoints to the North, South, East and West (v). The number of crop species at each plot was also counted (vi). In addition, (vii) the number of oil palms and (viii) the number of banana palms at each plot were counted. The number of crop plants within the vegetation plots was also counted. This included (ix) the number of mature oil palms, (x) the number of immature oil palms of less than five years (Hardter et al., 1997), (xi) the number of fallen dead oil palms and (xii) the number of dead standing oil palm at each plot. Finally, (xiii) the percentage epiphyte cover on four random oil palm trunks within a rectangular quadrat of 50 cm x 100 cm was measured.

Data analysis

To compare the abundance and number of orders between monoculture and polyculture smallholdings, we performed one-way Analyses of Variance (ANOVA). Count data were square-root transformed to meet the assumptions of the test (Ellison & Gotelli, 2004). We included different sampling months as blocks in the analysis.

The relationship between arthropod order richness and *in situ* habitat characteristics was compared using Generalized Linear Models (GLMs) (Schall, 1991). We used log-link function assuming a Poisson distribution to fit the models. Correlation tests were conducted to detect multi-co-linearity among the predictor variables. Only one of each pair of highly correlated explanatory variables were included in the analysis, as co-linearity can distort model estimation ($|r|>0.7$) (Dormann et al., 2013). Height of grass (coefficient of correlation, $r = -0.806$), was therefore excluded, while grass coverage was included in the model. Akaike Information Criterion (AIC) tests were conducted to select the most parsimonious models (Burnham & Anderson, 2002), with models with the lowest AIC scores were chosen. Under this criterion, the chosen model is the one that minimizes the Kullback-Leibler distance between the model and the truth (Burnham & Anderson, 2002). Akaike weights were computed to provide a measure of model selection uncertainty. All statistical analyses were computed in GenStat version 15 (VSN International).

Analysis of Similarity (ANOSIM) was used to compare arthropod order composition between monoculture and polyculture smallholdings. We also used SIMPER analysis to determine the contribution of each order to differences in the arthropod assemblages. The comparison of arthropod order composition between those collected in polyculture and monoculture smallholdings was made using non-metric multi-dimensional scaling (NMDS) (Clarke & Warwick, 2001). Bray-Curtis distance was used to calculate the resemblance metric between monoculture and polyculture smallholdings. ANOSIM, SIMPER and NMDS analysis were conducted in Primer version 6 (PRIMER-E Ltd).

Results

Arthropod responses to different farming practices

A total of 15 orders of terrestrial arthropods comprising 15,394 individuals were recorded (Table 2). Arthropods captured were 12 orders of Insecta, but only one order each for Arachnida, Diplopoda and Chilopoda. We found that the number of arthropod orders were significantly greater ($F_{1,119}$ = 17.27; p < 0.001) in polyculture smallholdings (mean ± S.E. = 4.717 ± 0.158 orders) than in monoculture smallholdings (mean ± S.E. = 3.817 ± 0.149 orders) (Fig. 1). No significant difference in terms of arthropod abundance ($F_{1,119}$ = 1.4; p = 0.239) was found between monoculture smallholdings (mean ± S.E. = 140.3 ± 16.2 individuals) and polyculture smallholdings (mean ± S.E. = 116.3 ± 13.77 individuals) (Fig. 2).

Arthropod order richness and in situ habitat characteristics

The most parsimonious model was selected according to the lowest AIC value of 120.26 and an R^2 of 15.98%. The predictive models showed that farming practice (slope = 0.21475), height of oil palm stand (slope = 0.01765) and number of immature oil palm (slope = 0.00546) were all positively associated with increasing arthropod order richness in oil palm smallholdings (Table 4).

Arthropod community composition

We found that polyculture smallholdings had an average similarity of 64.28%. Three orders, Hymenoptera (62.27%), Orthoptera (24.64%) and Araneae (5.11%), contributed more than 90% to the arthropod assemblage of polycultures. For monoculture smallholdings, the average similarity was 63.69%. Hymenoptera (68.21%) and Orthoptera (25.53%) represented the majority of arthropod orders and contributed approximately 94% to the arthropod assemblages of monocultures. The average dissimilarity between polyculture and monoculture smallholdings was 36.41%. We did not detect a significant difference in arthropod order composition between polyculture and monoculture smallholdings (ANOSIM, number of permutations = 999; Global R = 0.019; $p = 0.072$). The NMDS ordination revealed a stress level value of 0.18. Ordination plot showed no clear differences in ordinal composition between monoculture and polyculture plantations (Fig. 3).

Discussion

Responses of arthropods to different farming practices

We found that arthropod order richess was higher in polyculture smallholdings than in monoculture smallholdings. However, arthropod abundance did not differ significantly between the two smallholding types. Other studies have already showed that agricultural practice can affect animal biodiversity found in farmlands (Kross & Schaefer, 1998; Benton et al., 2003; Holzschuh et al., 2007; Rundlof et al., 2008; Azhar et al., 2014). Turner & Foster in 2009, found that most arthropods declined in abundance in monoculture oil palm plantations. However, some arthropods such as ants, woodlice, cockroaches and beetles favour monoculture oil palm plantations.

This study indicates that polyculture is a better farming practice than monoculture to maintain terrestrial arthropod diversity, perhaps because polyculture can increase habitat heterogeneity in farmlands. Polyculture farming can increase the floristic diversity and create moe variable vegetation structures. Our results are in line with a study by Weibull et al., (2003), who suggested that faunal diversity increases with habitat heterogeneity. Kross & Schaefer (1998), found that species richness of rove beetles (Coleoptera: Staphylinidae) collected using pitfall traps was highest in integrated farms with a mixture of crop plants compared to monoculture farms.

Effects of in situ habitat characteristics on the number of arthropod orders

All habitat characteristics at local scale showed significant effects on arthropod richness except for three variables which were removed from the modeling work because of multicollinearity. These were height of non-grass cover, number of mature oil palms and number of banana palms. It is therefore clear that habitat quality variables do have a significant effect on the number of arthropod orders. Amongst 13 habitat characteristics, the number of crop species, height of oil palm crop, and number of immature oil palms most strongly influenced the arthropod order richness. Local habitat quality variables explained 15.98% of the variation in arthropod order richness. In this study, the arthropod order richness inceased with polyculture farming. This may be because the multi-cropping habitat provides a wider range of food and hence more resources to support other fauna (Dennis et al., 1998). These results was similar to those of Wickramasinghe et al., (2004) and Haddad et al., (2001), who both found that plant species richness had a positive influence on arthropod species richness.

In this study, arthropod order richness also increased with height of oil palms. This may due to the fact that taller palms provide microhabitats such as epiphytes (Turner & Foster, 2006) that can be inhabited by different arthropod species at different trophic levels. The presence of epiphytes on palm stems is unlikely to affect the ground-dwelling arthropods. However, the flying or highly mobile insects belonging to some orders such as Lepidoptera, Diptera, and Orthoptera may be influenced by the presence of epiphytes. Height of oil palms may affect the amount of shading in oil palm plantations. Existing studies suggest that such result is associated with microclimate parameters such as air temperature, relative and specific humidity, vapour pressure and soil temperature (Turner & Foster, 2006; Luskin & Potts, 2011; Hardwick et al., 2015), but we did not include these parameters in our study. The results differ from a study on weaver ants (*Oecophylla smaragdina*), which are used to control bagworm infestation in oil palm plantations (Pierre & Idris, 2013). This study revealed that this one species of ants favored short oil palms to build nest. Although the study only focussed on one species of ant, but it indicated that height of oil palms can influence the abundance of arthropods in oil palm plantations.

Our results indicated that the arthropod order richness increased with increasing number of immature oil palms. A similar relationship was observed by Lowman (1985), whereby trees with younger leaves had a higher abundance of arthropods in the rainforest of Australia. This was mainly due to the fact that some insects prefer younger trees, which may explain the high number of arthropod orders in immature oil palms in this study. Luke et al., (2014), showed that ant abundance was positively influenced by heterogeneity in local-scale habitat characteristics in oil palm plantations. This indicates that habitat heterogeneity may increase resources for arthropods.

Arthropod order composition in different farming practices

Analysis of order composition of arthropods showed there was no significant difference in arthropod order composition between polyculture and monoculture smallholdings (Fig. 1). This implies that both farming practices hosted a similar composition of arthropods. However, it should be noted that this study was only carried out in smallholdings and results may differ in large-scale plantations. This is because the latter are usually characterized by a uniform stand age, covering a vast planted area of oil palm monocultures, and therefore show lower levels of habitat heterogeneity at these large scales (Azhar et al., 2015). Similar results were discussed in Fayle et al., (2010) and Koh (2008), where none of the *in situ* habitat characteristics in monoculture oil palm plantations had significant effects on butterfly or ant communities.

Polyculture farming in the context of wildlife-friendly agriculture

Wildlife-friendly agriculture or land sharing can implement agroecological methods including polyculture farming that promote on-farm biodiversity, and/or incorporate more small patches of natural habitat within the farming landscape (Kremen, 2015). In contrast, the land-sparing strategy supports isolating biodiversity conservation from agriculture, using intensive, high-yielding monocultural production in one portion of the landscape to meet food demands, thereby sparing up lands for biodiversity conservation elsewhere (Kremen, 2015; Phalan et al., 2012). The land-sharing strategy supports accomplishing both biodiversity conservation and agriculture in the same landscape, but was assumed to endure a yield penalty (Green et al., 2005; Phalan et al., 2012). We recommend that the focus of future research should be aimed at the impacts of polyculture farming on oil palm yield.

Conclusions

Conventional oil palm farming is mainly characterized by large-scale monoculture system and uniform stand age that is often hostile to farmland biodiversity. One possibility for developing the oil palm industry into a more biodiversity-friendly production system is for stakeholders (e.g. growers and government agencies) to work together to increase habitat heterogeity at the plantation scale. This can be achieved by promoting various conservation measures (e.g. maintaining forest patches and riparian vegetation within plantations), thereby maintaining as much of the existing farmland biodiversity as possible. It is clear that large-scale monoculture oil palm plantations have failed to protect biodiversity effectively (Koh & Wilcove, 2008; Edwards et al., 2010; Azhar et al., 2011), therefore polyculture farming should be considered by plantation companies as an alternative production strategy.

Our study indicates that polyculture farming as an alternative approach, may improve biodiversity conservation in oil palm smallhodlings and perhaps in large-scale plantations. Even though the significance of biodiversity maintenance may be low relative to the diversity of primary or secondary forest, these arthropods are likely to provide important ecosystem services (e.g. pest control and pollination) that benefit commercial oil palm cultivation (Altieri & Nicholls, 2004; Fisher et al., 2006; Scherr & McNeely, 2008; Tscharntke et al., 2012). This may provide an economic incentive for oil palm growers to make plantations or smallholdings hospitable to farmland biodiversity. Polyculture system therefore has the potential to improve farmland biodiversity conservation in oil palm production landscapes.

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Table 1

Summary statistics of habitat variables measured for monoculture and polyculture smallholdings.

Variable	Site	Mean	SD	Minimum	Median	Maximum
Canopy cover (%)	Polyculture	58.25	35.60	70	0	100
	Monoculture	73.67	22.28	25	75	100
Epiphyte cover (%)	Polyculture	22.73	19.33	0	20.47	64.69
	Monoculture	39.74	16.86	0	40.31	83.75
Number of banana plants	Polyculture	32.03	17.85	6	27	90
	Monoculture	0	0	0	0	0
Number of dead oil palms (fallen)	Polyculture	0.817	1.455	0	0	5
	Monoculture	1.4	2.035	0	0	8
Number of dead oil palms (standing)	Polyculture	0.4	1.061	0	0	5
	Monoculure	0.8	1.885	0	0	13
Grass cover (%)	Polyculture	31.21	27.32	0	21.25	86.88
	Monoculture	30.39	23.53	0	24.53	72.19
Mean height of grass (cm)	Polyculture	15.82	12.02	0	14.06	52.50

	Monoculture	15.91	12.22	0	15	56.88
Mean height of non-grass (cm)	Polyculture	23.63	15.30	0	22.44	77.50
	Monoculture	22.59	12.42	0	25.06	50.31
Mean height of oil palm canopy (m)	Polyculture	6.681	2.211	3.375	6.5	11.5
	Monoculture	9.069	2.894	3.75	8.5	14.75
Number of crop species	Polyculture	2	0	2	2	2
	Monoculture	1	0	1	1	1
Non-grass cover (%)	Polyculture	31.30	20.98	0	25.78	76.56
	Monoculture	26.70	21.84	0	21.25	75.31
Number of immature oil palm	Polyculture	10.67	9.906	0	7	28
	Monoculture	5.35	7.611	0	3	28
Number of mature oil palm	Polyculture	13.13	9.842	0	18	28
	Monoculture	20.68	5.350	0	21.5	30

Table 2

Summary statistics of arthropod count for monoculture and polyculture smallholdings.

Order	**Monoculture**		**Polyculture**	
	Total count	**Mean ± S.E.**	**Total count**	**Mean ± S.E.**
Aracnidae	54	0.900 ± 0.173	86	0.173 ± 0.185
Chilopoda	1	0.017 ± 0.017	0	0
Diplopoda	1	0.017 ± 0.017	31	0.517 ± 0.239
Blattodea	41	0.683 ± 0.232	31	0.517 ± 0.129
Coleoptera	41	0.683 ± 0.202	51	0.850 ± 0.138
Dermaptera	4	0.067 ± 0.033	11	0.183 ± 0.115
Diptera	135	2.250 ± 0.700	70	1.167 ± 0.262
Hemiptera	28	0.467 ± 0.140	53	0.883 ± 0.178
Homoptera	2	0.033 ± 0.023	0	0
Hymenoptera	7020	117.00 ± 14.55	5902	98.37 ± 13.58
Isoptera	3	0.050 ± 0.0284	8	0.133 ± 0.0769
Lepidoptera	20	0.333 ± 0.094	25	0.417 ± 0.093
Neuroptera	0	0	1	0.017 ± 0.017
Orthoptera	1066	17.77 ± 2.750	708	11.80 ± 1.136
Plasmatodea	0	0	1	0.017 ± 0.017

Table 3

All models were fitted to a dataset and the best models were selected by using R^2 and AIC values. The twelve predictor variables are coded as follows: CC, percentage canopy cover; E, percentage epiphyte cover; DOPS, number of dead oil palm (standing); HG, Height of grass; HNG, height of non-grass; HOPC, height of oil palm; TYP, type of farming practice; GC, percentage of grass cover; NGC, percentage of non-grass cover; OPI, number of immature oil palm.

Model	K: Terms	R^2	AIC	AICc	Delta	Relative Likelihood	Akaike's Weight
1	1: TYP	11.13	122.73	123.80	2.3	0.3166	0.1018
2	2: As model 1 + OPI	13.91	121.02	122.21	0.71	0.7012	0.2254
3	3: As model 2 + HOPC	15.98	120.26	121.50	0	1	0.3214
4	4: As model 3 + HG	16.61	121.41	122.83	1.33	0.5143	0.1653
5	5: As model 4 + NGC	17.25	122.56	124.16	2.66	0.2645	0.0850
6	6: As model 5 + HNG	18.23	123.26	125.09	3.59	0.1661	0.0534
7	7: As model 6 + E	18.33	125.11	127.23	5.73	0.0570	0.0183
8	8: As model 7 + DOPS	18.40	127.03	129.47	7.97	0.0186	0.0060
9	9: As model 8 + OPM	18.41	129.01	131.82	10.32	0.0057	0.0018
10	10: As model 9 + CC	18.45	129.04	132.26	10.76	0.0046	0.0015

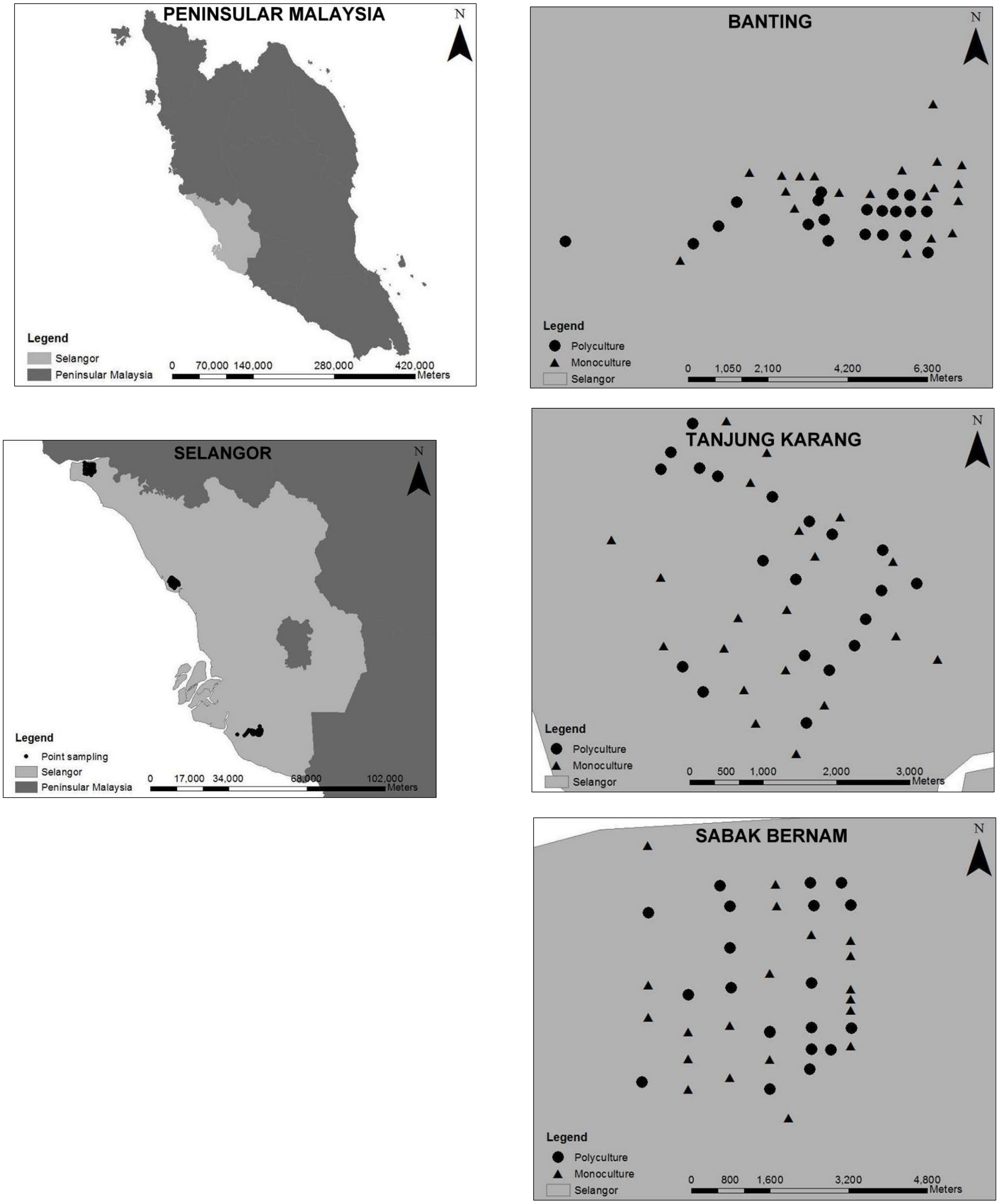

Fig. 1. Map of study area showing 120 sampling sites within oil palm smallholdings in Peninsular Malaysia.

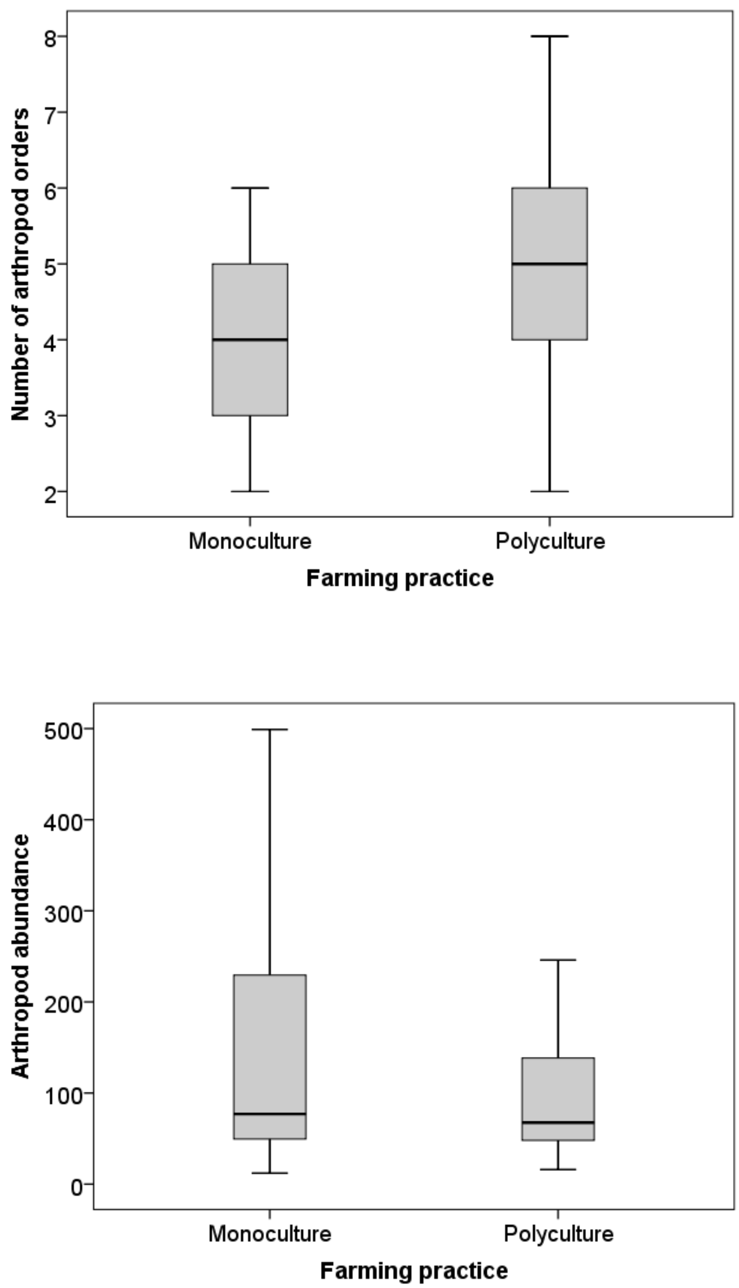

Fig. 2. Box plots showing number of arthropod orders and abundance of arthropods per sample in monoculture and polyculture smallholdings. Polyculture smallholdings maintained greater number of arthropod order than monoculture smallholdings. Both farming practices maintained similar arthropod abundance.

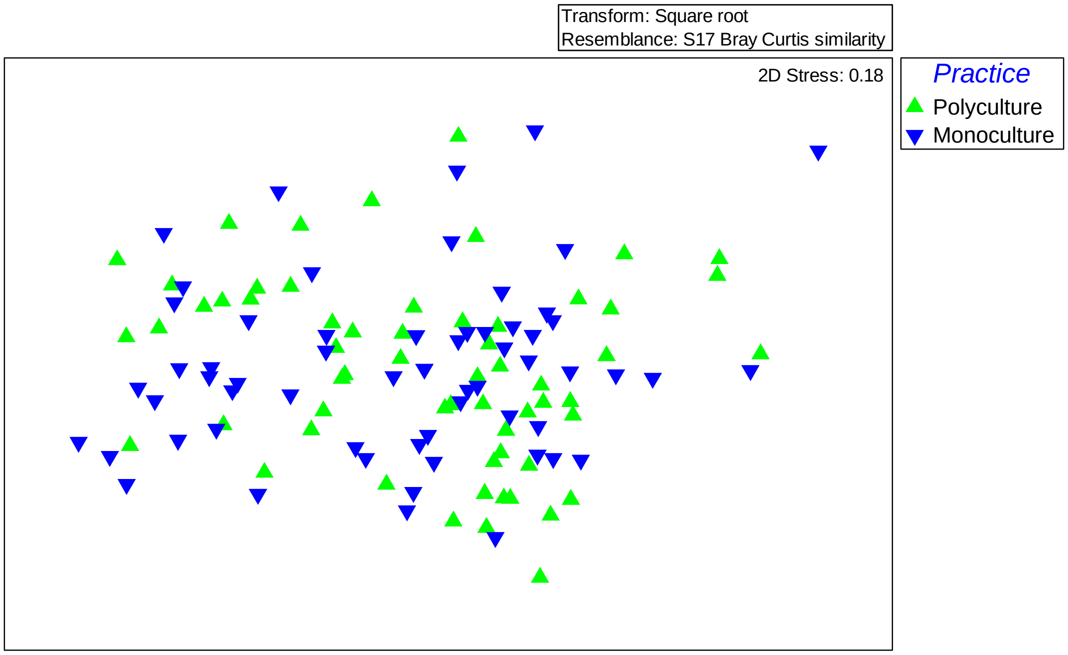

Fig. 3. Non-metric multidimensional scaling (NMDS) ordination comparing the arthropod community between polyculture smallholdings and monoculture smallholdings.