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Research article

Change in ground-dwelling arthropod communities in different agroecosystems in Wang Nam Khiao, Nakhon Ratchasima province, Thailand

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Abstract

The impact of agricultural practices on the biodiversity of arthropods is basic knowledge that is required for the assessment of soil health. In addition, arthropod diversity and abundance may be indirectly limited by disturbance of the soil surface; however, there are very few data available regarding this issue. The aim of this study was to examine the effects of the agricultural production system on soil arthropod communities. Arthropods were sampled using a Tullgren funnel in three types of agricultural production system and in total, 12 macro-arthropod orders were found. The results showed that ground-dwelling arthropod communities were significantly different among the three practices. The most diverse arthropod communities were found in organic farming (species mean ± SD = 49 ± 4.2) compared to the other agricultural production systems; thus, different practices affected the ground-dwelling arthropod communities in agricultural land in Northeast Thailand. The results clearly revealed that a change in the diversity and abundance of some arthropod groups was associated with agricultural activities and in particular, isopods, spiders and beetles. Thus, no single taxon of soil arthropods could be used as a bioindicator of soil health and land use intensity.

Introduction

Ground-dwelling arthropod communities have been shown to vary in abundance and species composition according to changes in vegetation (Heyborne et al., 2003; Liu et al., 2016; Medianero et al., 2007) and soil conditions (Brussaard et al., 1997). Moreover, intensification of land use has occurred mainly through associated changes in food and habitat, as well as through the physical and chemical compositions of the soil and soil fauna biodiversity (Anderson, 1988; Batary et al., 2012; Padmavathy and Poyyamoli, 2013; Marliac et al., 2015). These changes may provide favorable or unfavorable conditions for some species of ground- dwelling arthropods (GDAs). From previous studies, it was found that GDAs, such as isopods, ground beetles, rove beetles, spiders and ants, were highly tolerant of a wide range of environmental conditions from agricultural pollution (Anderson et al., 2001; Büchs, 2003; Jörg and Malt, 2003). Ants differed strongly in their sensitivity to environmental stress or change, which had occurred because of the intensity of land use (Folgarait, 1998). Thus, various groups of GDAs are now currently used as a standard in the assessment of the environmental risks from soil in agricultural production systems (Clark, 1999; Büchs, 2003; Aibek and Yamane, 2015; Madzaric et al., 2018).

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The commonest consequence of converting tropical forests for agricultural purposes is the mosaic of fragments of vegetation, which are managed by differences in agricultural production systems, such as chemical usage, organic farming and good agriculture practices (Clark, 1999). The intensification of land use of the natural habitat could result in the loss of or changes in species and composition of animals in different groups including the arthropods (Folgarait, 1998; Büchs, 2003; Jörg and Malt, 2003; Aibek and Yamane, 2015; Bharti et al., 2016; Rivers, et al., 2018). Thus, it is necessary to understand the effects of land use intensification occurring in agricultural soils, which correlate to soil health in terms of changes in the soil chemical composition and in the food and habitat of GDAs. It is further important to examine how the richness and composition of species change in agricultural areas that are managed by differences in agricultural production systems.

The present study was undertaken within the agriculture landscape, which differs with the agricultural production system. This research aimed to examine the effects of agricultural production systems on the richness and composition of GDAs and to determine whether the change in the presence of GDA dominants was correlated with soil conditions. Finally, the results could be considered in a broader view for conserving agricultural soils and as a bioindicator in sustainable agricultural management practices.

Material and Methods

Study site

This study was conducted in an agricultural area near the "Khao Phaeng Ma Reforestation Project to Honour His Majesty the King" in Wang Nam Khiao district, Nakhon Ratchasima province, Northeast Thailand (14.343° N and 101.897° W). The average elevation is 500 m above mean sea level and based on data from the meteorological station at Wang Nam Khiao (2012–2013), the seasons in this area are characterized by the temperature, which is cool in winter (November to the middle of January), dry season (the middle of February to April) and wet season (July to August) . The mean annual temperature ranges from 2°C (minimum) to 35°C (maximum). The mean (± SE) of the maximum and minimum annual relative humidity is 41.74 ± 7.19 % and mean (± SE) annual air temperature of is 36.65 ± 4.41°C.

Three study areas were chosen based on the application methods used for vegetable farming, namely organic farming, good agricultural practices and chemical methods (Table 1).

A conventional agricultural system (CAS) was defined as using a regime in which vegetables are grown using chemical insecticide, fertilizers and growth hormones. Good agricultural practice (GAP) was defined as a method for cultivating crops for consumers by taking into consideration the crop's economic viability and food safety and quality controls, so that pesticides are not used and instead, fertilizers are based on organic compounds with botanical or natural insecticides and growth hormones used to improve the quality of the soil and to control insect pests. An organic farming system (OFS) was defined as a method for growing crops without the use of pesticides, fertilizers and growth hormones and instead, biological methods and management practices are used to improve the quality of the soil and to control insect pests. The major vegetables grown using the OFS and GAP included red leaf lettuce, oak leaf lettuce, butterhead, green oak lettuce, red oak lettuce, pumpkin, cucumber, pepper and tomato. Under the CAS, the main vegetables grown were pumpkin, cucumber, chili and corn. For this research, data were collected from three plots (50m × 50m) established in each of the three agricultural production systems with 20 m distance between plots (Table 1).

Data collection

Soil chemical properties

Soil samples of approximately 500 g were collected at a depth of 0-5 cm. Five replicates of these soil samples were taken from open areas at least 1 m from the nearest vegetable planted to exclude the influence of plants on the soil properties. The parameters measured were: soil pH, organic matter, total nitrogen and potassium. The soil samples were stored at 5–10°C until analysis and were analyzed in the laboratory for the pH and concentration of organic matter, total nitrogen, potassium and available phosphorous. A soil pH meter was used in a pH 7 buffer solution to determine the degree of acidity or alkalinity of the soil.

Soil organic matter was analyzed using the Walkley-Black acid digestion method (Bray and Kurtz, 1945) and the total available nitrogen status of the soil was extracted using the Kjeldahl method

Table 1 Three types of agricultural production system in the study

Site Name	Abbreviation	Management/Land use activities	Vegetation
Conventional agricultural system	CAS	All-year high-level of pesticide application; annual crop (one or two harvests per year); modern tractor ploughing with three harvests per year.	Cassava, corn, chili, papaya, cucumber, melons, pumpkin.
Good agricultural practices system	GAP	All-year low-level of pesticide application compost and liquid fertilizer (e.g. manure); annual crop (three harvests per year); traditional ploughing with three harvests per year (farmers work the land with a weeding tool).	Green oak lettuce, Red oak lettuce, Cos lettuce, Butterhead lettuce, Iceberg lettuce, red leaf lettuce, cucumber, pumpkin.
Organic farming system	OFS	All-year no level of conventionally managed compost and liquid fertilizer (e.g. manure), mixed cropping of a year (three harvests per year), traditional ploughing with three harvests per year (farmers work the land with a weeding tool).	Green oak, Red oak, Cos lettuce, Butterhead lettuce, Iceberg lettuce, Red Leaf lettuce, cucumber, pumpkin, Roselle.

(Bremner, 1965). The available potassium of the soil was extracted using 1 M pH7.0 (NH_4OAc), measured with a flame spectrophotometer and determined using the the Bray II method (Mehlich, 1978). The data for the chemical properties of soil were log-transformed to normalize the variances before being statistically analyzed (Sparks, 1996).

Ground-dwelling arthropods

Ten 1 m^2 quadrats were randomly sampled for each site. The litter and surface soil were scraped to a depth of 3 cm from the ground surface and sifted through a 1 cm wire mesh sieve to exclude larger debris. After sifting, each sample was transferred to a debris bag for transportation to the field station where Tullgren funnels were set up (Ozanne, 2005). After arriving at the field station, the contents of each debris bag were weighed and divided into 10 approximately equal samples before being placed in the Tullgren funnels. Soil and litter-dwelling organisms were extracted over 48 hr using a 60 W incandescent light. Specimens were preserved in 80% alcohol prior to processing. Collections were conducted in both the rainy season and dry season in 2013.

Identification of ground-dwelling arthropods

Collections of GDAs in 10 Tullgren funnels were sorted and classified into two taxonomic levels (arthropod order and family). GDA orders were identified using the systematic keys of Aoki (2015) and the author's taxonomic expertise with these groups. Ants were identified by reference to the insect collection at the Department of National Parks, Wildlife and Plant Conservation (DNP) and reliable digital resources (http://www.antweb.org and http://www.antbase.de). Some ant specimens were identified with the help of a myrmecologist, Professor Seiki Yamane (Japan). All ant individuals were sorted into species and morphospecies, while other arthropods were identified to the family level. The number of individuals for each ant species or arthropod family were counted for analysis.

Data analysis

Species richness was determined by the total number of GDA species. This was calculated and the the frequency of occurrence (F) of each GDA family in each study area was analyzed separately (F_{areas}) using the presence or absence of GDAs. Abundance was considered as the number of individual workers collecting in Tullgren funnels. In addition, the Shannon diversity index (H') and the evenness (E) of agricultural production system (OFS, GAP or CAS) were calculated. Univariate analysis of variance (ANOVA) was conducted to compare the richness, abundance, H' and E, and also soil environmental variables (soil pH, N, OM, K, P) among the study sites, as well as to test for differences between the seasons. Pairwise comparisons (least significant difference post-hoc tests) were made when the differences were considered significant at $p < 0.05$ with the study areas and seasons as the explanatory variables. The normality and homoscedasticity of the data were confirmed prior to the analyses using the Shapiro-Wilk test and Levene's test. All data were transformed to reduce heteroscedasticity for the analysis. All univariate statistical analyses were performed using the PASW software package (ver. 20.0.0 for Windows; SPSS Inc.; Chicago, IL, USA).

The soil environmental variables (soil pH, N, OM, K, and P), seasons and site variables were examined to identify any relationships to the GDA species assemblage using canonical correspondence analysis (CCA). These analyses were done using the PC-ORD version 5 (MjM Software, Gleneden Beach, Oregon, USA).

Results

Community structure of macro-arthropods

In total, 12 macro-arthropod orders were found (Appendix Table 1). The univariate ANOVA revealed that the richness of the GDAs differed significantly among the study sites ($p < 0.05$; Table 2) while there were no differences found between the wet and dry seasons ($p > 0.05$).

Table 2 Effects of agricultural production systems on community composition of ground-dwelling arthropods and soil environmental variables using agricultural systems and season as fixed factors

Dependent variable	Source of variation											
	Plot				Season				Plot*Season			
	d.f.n.	*d.f.d.*	F	P-value	*d.f.n.*	*d.f.d.*	F	P-value	*d.f.n.*	*d.f.d.*	F	P-value
Ground-dwelling arthropod												
Richness	2	12	10.2	**0.002**	1	12	0.59	0.45	2	12	0.93	**0.004**
Abundance	2	12	3.5	**0.05**	1	12	0.46	0.94	2	12	6.93	**0.01**
Diversity index (H')	2	12	5.7	**0.02**	1	12	0.001	0.99	2	12	1.05	0.38
Evenness (E)	2	12	0.68	0.53	1	12	0.007	0.93	2	12	5.39	**0.02**
Soil environmental variables												
Available phosphorus	2	12	78.26	**<0.001**	1	12	0.44	0.52	2	12	0.92	0.42
Potassium (%)	2	12	11.75	**0.001**	1	12	1.27	0.28	2	12	0.04	0.96
Organic matter (%)	2	12	1.08	0.37	1	12	0.53	0.48	2	12	0.16	0.85
Soil pH	2	12	86.85	**<0.001**	1	12	0.96	0.34	2	12	0.98	0.40
Total nitrogen (%)	2	12	1.07	0.37	1	12	0.01	0.92	2	12	0.01	0.99

Bold text indicates the statistical significance tested at $p < 0.05$, *d.f.n.* = degree of freedom from between the columns and *d.f.d.* = degree of freedom from within the columns.

The richness was significantly higher in the OFS than the CAS and the GAP (Fig. 1A). Moreover, an interaction was detected between the study sites and seasons. The mean richness was higher in the OFS than the GAP and CAS during the dry season ($p < 0.05$; Fig. 2A), and the richness was slightly higher in the OFS than the GAP and CAS during the wet season, but the difference was not significant.

Abundance was significantly higher in the OFS than the CAS and GAP (Fig. 1B), but there were no differences found between the wet and dry seasons (Table 2). However, a significant interaction was detected between the study sites and seasons. The mean abundance was higher in the OFS than the GAP and CAS during the dry season ($p < 0.05$; Fig. 2B), as well as slightly higher in the OFS than the GAP and CAS during the wet season, but the difference was not significant.

The diversity index (H') was greater in the OFS, and H' was not significantly different between the OFS and GAP (Table 2; Fig. 1C). There were no differences found between the wet and dry seasons. Moreover, there was no significant interaction between the study sites and seasons.

The evenness *(E)* was slightly higher in the GAP than the CAS and OFS, but the difference was not significant (Table 2; Fig. 1D). Additionally, there were no significant differences for *E* between the wet and dry seasons; however, a significant interaction was detected between the study sites and seasons. The mean *E* was higher in the CAS than the GAP and OFS during the dry season ($p < 0.05$; Fig. 2C), and the mean E was higher in the GAP than the OFS and CAS during the wet season, but the difference was not significant.

Soil quality

The available phosphorus was significantly higher in the OFS than in the CAS and GAP (Table 2; Fig. 3A) while there were no significant differences found between the wet and dry seasons. In addition, there no significant interaction between the study sites and seasons. Potassium (%) was significantly higher in the GAP than the OFS and the CAS (Table 2; Fig. 3B), but there were no significant differences between the wet and dry seasons, nor between the study sites and seasons. The organic matter (%) was higher in the GAP followed by the OFS and the CAS (Table 2; Fig. 3C). However, there were no significant differences between the wet and dry seasons, nor between the study sites and seasons. The soil pH was significantly higher in the OFS than the GAP and the CAS (Table 2; Fig. 3D) while again, there were no differences between the wet and dry seasons, nor between the study sites and seasons. The total nitrogen available in the soil (%) was slightly higher in the GAP and OFS than the CAS (Table 2; Fig. 3E). However, there were no significant differences between the wet and dry seasons, nor between the study sites and seasons.

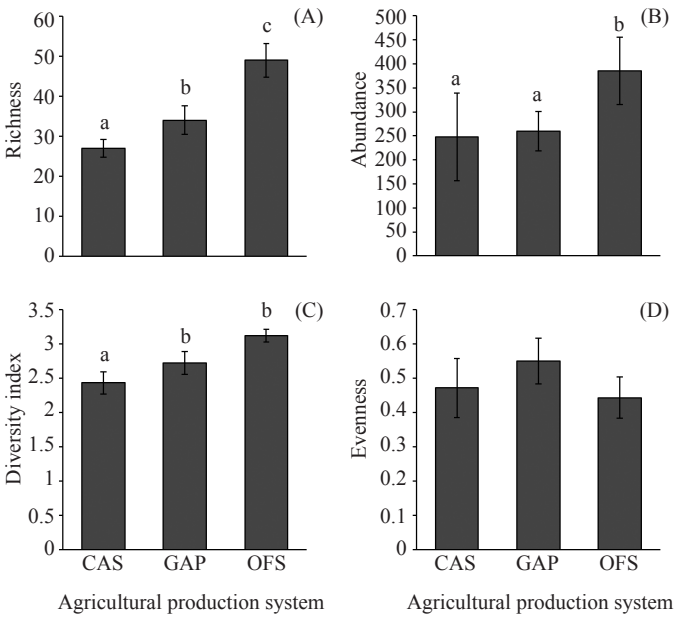

Fig. 1 Mean (±SE) of: (A) richness; (B) abundance; (C) diversity index; (D) evenness of ground-dwelling arthropods in the different agricultural production system, where CAS = conventional agricultural system, GAP = good agricultural practice system, OFS = organic farming system and different lowercase letters above columns indicate significant differences among groups at $p < 0.05$

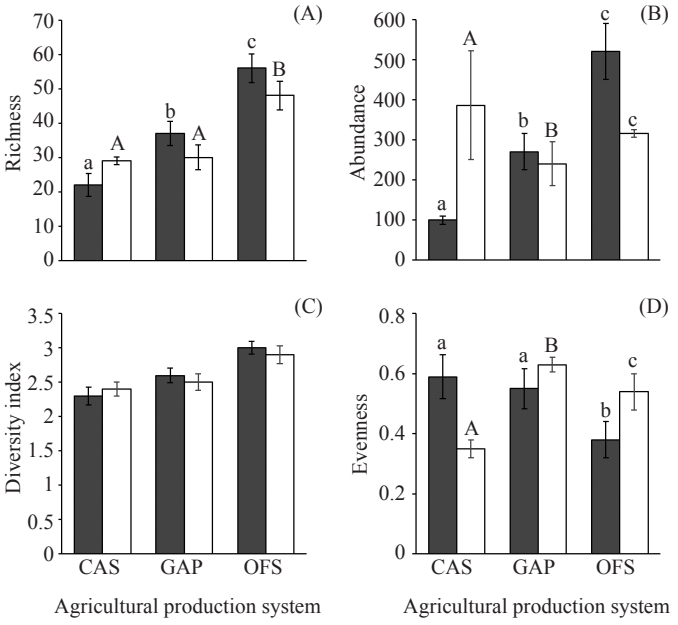

Fig. 2 Mean (±SE) of: (A) richness; (B) abundance; (C) diversity index; (D) evenness of ground-dwelling arthropods in the dry season (hatched bars) and wet season (clear bars) of each agricultural production system, where CAS = conventional agricultural system, GAP = good agricultural practice system, OFS = organic farming system, different lowercase letters indicate significant differences among production systems in dry season and uppercase letters for wet season at $p < 0.05$

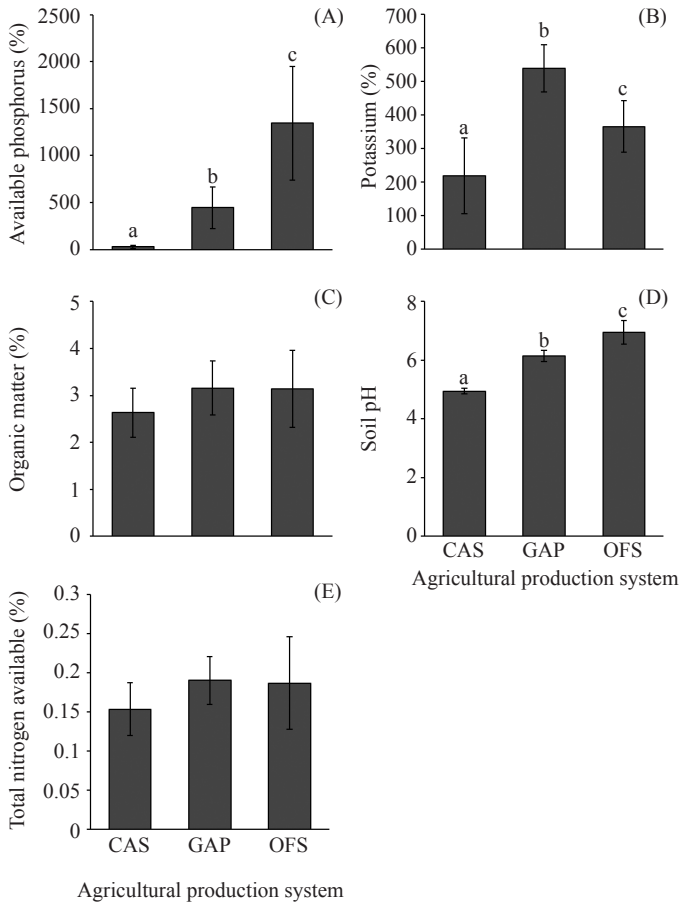

Fig. 3 Mean (±SE) of: (A) available phosphorus; (B) potassium; (C) organic matter; (D) soil pH; (E) total nitrogen available in the soil in different agricultural production systems, where CAS = conventional agricultural system, GAP = good agricultural practice system, OFS = organic farming system and different lowercase letters above columns indicate significant differences among groups at $p < 0.05$

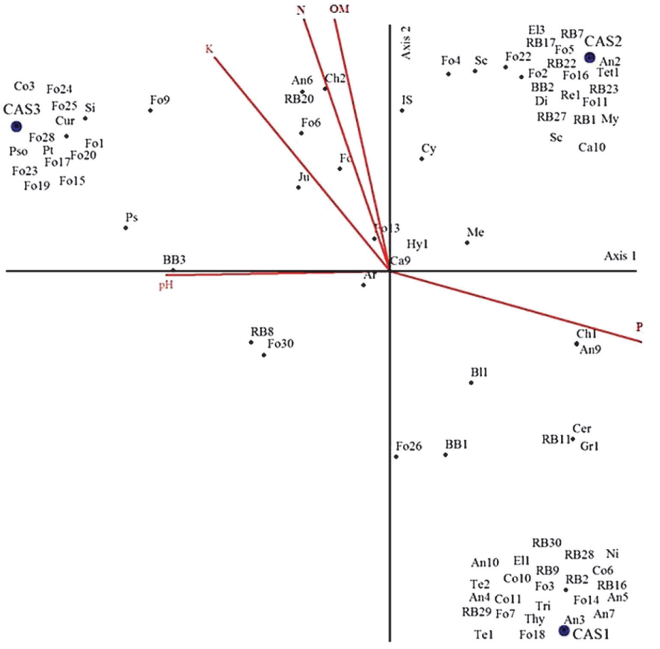

Fig. 4 Canonical correspondence analysis of arthropod composition in the conventional agricultural system (CAS), where lines show the direction and strength of the relationship among the measured parameters (P = available phosphorus, K = potassium, OM = organic matter, pH = soil pH, N = total nitrogen available) and the three CAS plots (CAS1, CAS2, CAS3) with respect to the structure of the ant assemblage in each study plot a d abbreviations are provided in Appendix Table 1

Soil quality and habitat characteristic as explanatory variables for macro-arthropods

In the CAS plots, the percentages of K, total N, OM and P were negatively correlated with the macro-arthropods while the pH was positively related with the undescribed Scolytidae, BB3 (Appendix Table 1). The CCA showed that the habitat characteristic was positively correlated with some morphospecies of the macro-arthropod groups, but negatively correlated with approximately 20 morphospecies of macro-arthropods (Fig. 4).

In the GAP plots, the percentages of the total N, OM and P were negatively correlated with the macro-arthropods. On the other hand, K was positively correlated with Carabidae under.2 (Ca6) and Leiotidae (Lei), and soil pH was positively related with 14 macro-arthropod species. The CCA showed that the habitat characteristic was positively correlated with some morphospecies of the macro-arthropod groups, but negatively correlated with approximately 25 morphospecies of macro-arthropods (Fig. 5).

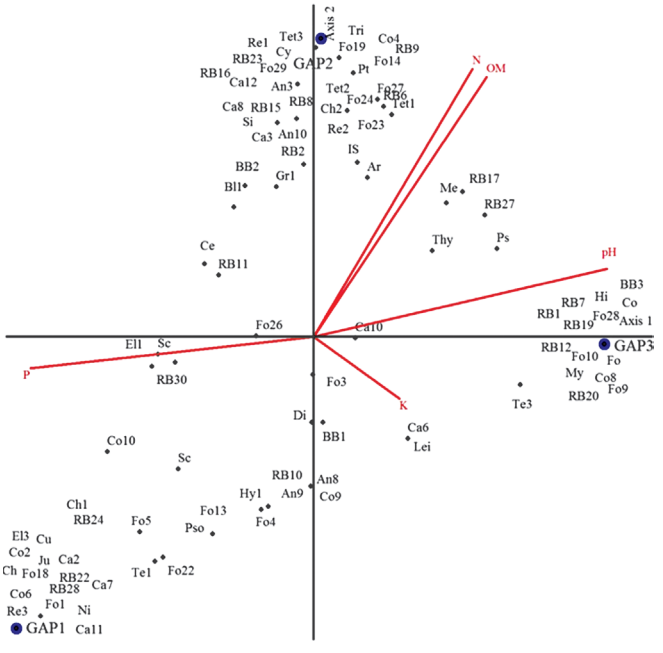

Fig. 5 Canonical correspondence analysis of arthropod composition in the good agricultural practice system (GAP), where lines show the direction and strength of the relationship among the measured parameters (P = available phosphorus, K = potassium, OM = organic matter, pH = soil pH, N = total nitrogen available) and the three GAP plots (GAP1, GAP2, GAP3) with respect to the structure of the ant assemblage in each study plot a d abbreviations are provided in Appendix Table 1

In the OFS plots, the percentages of K, total N, OM and P were negatively correlated with the macro-arthropods while the soil pH was positively correlated with Scolytidae under.3 (BB3), Scolytidae under.2 (BB2), Staphylinidae under.6 (RB29), Staphylinidae under.16 (RB16), *Monomorium talpa* (Fo10) and *Pheidole plagiaria* (Fo16). The CCA showed that the habitat characteristic at OFS2 were positively correlated with the morphospecies of the macro-arthropod groups, which were the same as the macro-arthropods groups found at OFS3. A negative correlation with approximately 20 morphospecies of macro-arthropods was also found (Fig. 6).

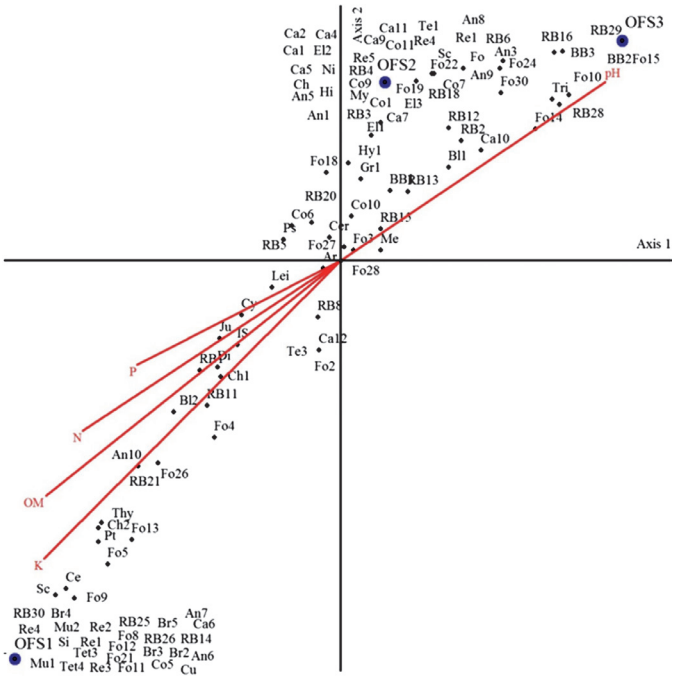

Fig. 6 Canonical correspondence analysis of arthropod composition in the organic farming system (OFS), where lines show the direction and strength of the relationship among the measured parameters (P = available phosphorus, K = potassium, OM = organic matter, pH = soil pH, N = total nitrogen available) and the three OFS plots (OFS1, OFS2, OFS3) with respect to the structure of the ant assemblage in each study plot a d abbreviations are provided in Appendix Table 1

Discussion

This study found that the GDA community was dominated by beetles and ants in terms of richness, abundance and the percentage of the frequency of occurrence (FO) in all agricultural production systems, which is a general trait of the GDA assemblages in tropical agrosystems (Büchs, 2003; Crotty et al., 2015; Bharti et al., 2016) and forest ecosystems (Decaëns et al., 2006). Interestingly, spiders, isopods and rove beetles had larger values of FO (> 50 %) for the OFS than for the CAS and GAP. The presence of these groups may depend on the agricultural production system in which the OFS might be a more appropriate management practice for spider, isopod and rove beetle assemblages. Thus, the FO of spiders, isopods and rove beetles may have importance for other living animals by determining the soil environment in tropical agroecosystems; furthermore, they have been documented in previous research in which they were found to be the bioindicator in the changes of agricultural land use (Clark, 1999; Büchs, 2003; Bharti et al., 2016).

The effects of agricultural management practices on the richness, abundance and diversity index (*H'*) of the GDAs produced significant differences among the agricultural production systems. The OFS displayed greater richness and abundance compared with the CAS and the GAP ($p < 0.01$), and there were larger values of *H*' in the OFS and the GAP than the CAS ($p < 0.01$). In the study areas, some agricultural production system that explained the changes in those values were related to the management and land use activities such as level of conventional management, pesticide, ploughing techniques, crop rotation and species (Table 1). In particular, the high level of conventionally managed pesticide application for the CAS could have had an effect on the assemblage of the GDA, and also the ploughing techniques, crop rotation and species could create changes in the microclimatic conditions (temperature, moisture content and soil porosity) aboveground and belowground (Folgarait, 1998). Thus, one possible reason is that these management procedures and activities in the agroecosystems may have caused a reduction in the richness and abundance of the GDA, which have been reported in previous research (Blake et al., 1994; Gobbi and Fontaneto, 2008). Another possibility is that these disturbances could be caused by a decrease in suitable habitat conditions of the GDA in the study areas for the CAS, which was also found in other agricultural sites using chemicals (Jörg and Malt, 2003; Krauss et al., 2011; Padmavathy and Poyyamoli, 2013; Liu et al., 2016).

Agricultural system practices may also have caused changes in the soil chemical properties at the study sites. The results of the current study indicated high values of available phosphorus and soil pH in the OFS and GAP rather than in the CAS ($p < 0.05$). Thus, in this study, it was not exactly clear what was the origin of the high values of available phosphorus and potassium in the OFS and GAP. However, a major possible source of available phosphorus and potassium could have been from agricultural activities and their associated agricultural system practices (Ademba et al., 2015). At the same time, the application of animal manure may also have altered the soil pH. A lower rate of soil pH was found in the CAS, which could have been due to the reduced use of animal manure as a means of adding nutrients and organic matter to the soil, resulting in the soil in the CAS being more acidic than in the OFS and GAP.

The CCA impact on the GDAs based on the soil environmental variables in the plots for each agricultural management practice showed that soil pH may be a significant factor for the presence of some groups of GDAs including Scolytidae undet.3 (BB3) in the CFS and GAP, and Scolytidae undet.2, *Paratrechina* sp.1 and *Monomorium talpa* in the OFS. The CCA analysis of the GDA composition and soil quality were separated from the different plots of each agricultural management practice. All the results of the CCA analysis displayed some groups of the GDA as isolated occurrences, while some were specific occurrences, which were related to the plots. The results of this study clearly showed that a larger number of species-specific

habitats were found in only one area of the OFS. Interestingly, some of the natural enemy groups like Braconidae, Mutillidae, and Reduviidae were found in the OFS, but not in the CFS. In contrast, invasive ant species had a high richness and abundance in the CFS.

In conclusion, the results revealed that agricultural production systems might impact GDAs within the study areas of this research. Furthermore, the conventional agricultural system could be the cause of the decrease in diversity, abundance of biodiversity and abundance of GDAs, as well as the decline in natural enemy groups (Letourneau and Bothwell, 2008; Krauss, et al., 2011; Rivers, et al., 2018). On the other hand, organic farming systems provided a positive influence on the species richness and abundance of the GDA taxa. These systems also provided good agricultural conditions as a habitat source for the living species of the GDAs with the benefits of an ecosystems service (Batary et al., 2012; Padmavathy and Poyyamoli, 2013; Marliac et al., 2015). As such, some of the GDA species (such as the Braconidae, Mutillidae, Reduviidae, ground beetle and spider) play a role in the ability of natural enemies to control insect pests for plants, and soil modification (Anderson, 1988, Folgarait, 1998). In contrast, some of the GDAs like the rove beetle, ground beetle, grasshopper and Isopoda are considered sensitive bioindicators of agricultural soil ecosystems (Folgarait, 1998; Andersen, 2001; Andersen and Majer, 2004; Madzaric et al., 2018).

Conflict of Interest

The authors declare that there are no conflicts of interest.

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Supplementary Information

Appendix Table 1 List of ground-dwelling arthropods showing numbers of individuals

Class/Order/ Family/Species	Abbreviation	CAS	GAP	OFS	Total
Arachnida					
Araneae; Unknow	Ar	37	52	73	162
Opiliones; unknow	Op	0	0	3	3
Pseudoscorpionida; Unknow	Ps	5	45	11	61
Chilopoda					
Geophilomorpha; Geophilidae	Ch1	6	3	25	34
Lithobiomorpha; Lithobiidae	Ch2	13	3	22	38
Diplopoda					
Julida; Parajulidae	Ju	6	4	18	28
Polydesmida	Me	10	63	49	122
Insecta					
Blattodea					
Blatellidae					
Blatella sp.1	Bl1	11	14	16	41
Blatella sp.2	Bl2	0	0	7	7
Coleotera					
Anthicidae					
Anthicidae undet.1	An1	0	0	1	1
Anthicidae undet.10	An2	1	0	0	1
Anthicidae undet.11	An3	3	13	2	18
Anthicidae undet.12	An4	2	0	0	2
Anthicidae undet.2	An5	1	0	3	4
Anthicidae undet.3	An6	2	0	3	5
Anthicidae undet.4	An7	1	0	2	3
Anthicidae undet.6	An8	0	2	3	5
Anthicidae undet.7	An9	4	2	2	8
Anthicidae undet.8	An10	1	1	3	5
Carabidae					
Carabidae undet.1	Ca1	0	0	21	21
Carabidae undet.10	Ca2	0	11	5	16
Carabidae undet.11	Ca3	0	6	0	6
Carabidae undet.12	Ca4	0	0	2	2
Carabidae undet.13	Ca5	0	0	1	1
Carabidae undet.2	Ca6	0	3	1	4
Carabidae undet.3	Ca7	0	17	38	55
Carabidae undet.4	Ca8	0	3	0	3
Carabidae undet.5	Ca9	3	0	3	6
Carabidae undet.6	Ca10	2	7	6	15
Carabidae undet.7	Ca11	0	1	1	2
Carabidae undet.9	Ca12	0	6	2	8

Appendix Table 1 Continued

Class/Order/ Family/Species	Abbreviation	CAS	GAP	OFS	Total
Cerylonidae					
Hypodacnella sp.1	Ce	0	68	233	301
Chrysomeloidae					
Chysomeloidae undet.1	Ch	0	5	28	33
Coccinellidae					
Cocinellidae undet.1	Co	0	3	0	3
Cucujidae	Cu	0	4	9	13
Curculionidae	Cur	1	0	0	1
Elateridae					
Elateridae undet.1	El1	1	9	10	20
Elateridae undet.2	El2	0	0	3	3
Elateridae undet.3	El3	1	1	10	12
Histeridae	Hi	0	1	1	2
Hydrochidae					
Hydrochus sp.1	Hy1	15	14	41	70
Hydrophilidae					
Cercyon sp.1	Cer	3	0	14	17
Leiotidae	Lei	0	6	11	17
Mycetophagidae	My	1	3	1	5
Nitidulidae	Ni	2	6	2	10
Ptilidae	Pt	1	44	25	70
Scarabaeidae	Sc	10	11	24	45
Scolytidae					
Scolytidae undet.1	BB1	9	53	14	76
Scolytidae undet.2	BB2	1	4	2	7
Scolytidae undet.3	BB3	7	4	4	15
Scydmaenidae	Sc	7	43	9	59
Silvanidae	Si	25	29	22	76
Staphylinidae					
Astenus sp.1	RB1	1	1	2	4
Carpelimus sp.1	RB2	14	102	85	201
Cratna sp.1	RB3	0	0	1	1
Cratna sp.2	RB4	0	0	1	1
Philiosis sp.1	RB5	0	0	11	11
Pselaphidae sp.2	RB6	0	9	20	29
Pselaphidae sp.3	RB7	1	4	0	5
Staphylinidae undet.1	RB8	7	26	55	88
Staphylinidae undet.10	RB9	2	6	0	8
Staphylinidae undet.11	RB10	0	2	0	2
Staphylinidae undet.13	RB11	3	45	28	76
Staphylinidae undet.15	RB12	0	4	9	13
Staphylinidae undet.16	RB13	0	0	9	9
Staphylinidae undet.17	RB14	0	0	1	1
Staphylinidae undet.18	RB15	0	7	7	14
Staphylinidae undet.2	RB16	1	54	7	62
Staphylinidae undet.22	RB17	3	2	0	5
Staphylinidae undet.24	RB18	0	0	1	1
Staphylinidae undet.25	RB19	0	11	0	11
Staphylinidae undet.3	RB20	2	24	12	38
Staphylinidae undet.30	RB21	0	0	3	3

Appendix Table 1 Continued

Class/Order/ Family/Species	Abbreviation	CAS	GAP	OFS	Total
Staphylinidae undet.31	RB22	1	5	0	6
Staphylinidae undet.32	RB23	1	9	0	10
Staphylinidae undet.33	RB24	0	1	0	1
Staphylinidae undet.34	RB25	0	0	1	1
Staphylinidae undet.35	RB26	0	0	1	1
Staphylinidae undet.4	RB27	1	19	0	20
Staphylinidae undet.5	RB28	2	12	29	43
Staphylinidae undet.6	RB29	1	0	8	9
Staphylinidae undet.9	RB30	5	21	5	31
Tenebrionidae undet.1	Te1	1	1	3	5
Tenebrionidae undet.2	Te2	1	0	0	1
Tenebrionidae undet.3	Te3	0	7	2	9
Coleoptera Unidentified species					
Cole-unknow.1	Co1	0	0	1	1
Cole-unknow.2	Co2	0	1	0	1
Cole-unknow.3	Co3	2	0	0	2
Cole-unknow.4	Co4	0	11	0	11
Cole-unknow.5	Co5	0	0	2	2
Cole-unknow.6	Co6	5	4	4	13
Cole-unknow.7	Co7	0	0	5	5
Cole-unknow.8	Co8	0	1	0	1
Cole-unknow.9	Co9	0	2	4	6
Cole-unknow.10	Co10	4	20	4	28
Cole-unknow.11	Co11	1	0	1	2
Dermaptera					
Forficulidae	Fo	7	4	6	17
Diplura	Di	2	7	26	35
Hemiptera					
Cydnidae	Cy	7	66	32	105
Reduviidae					
Reduviidae sp.1	Re1	2	11	3	16
Reduviidae sp.2	Re2	0	4	4	4
Reduviidae sp.3	Re3	0	1	5	6
Reduviidae sp.4	Re4	0	0	4	4
Reduviidae sp.5	Re5	0	0	11	11
Hymenoptera					
Braconidae					
Braconidae sp.1	Br1	0	0	6	6
Braconidae sp.2	Br2	0	0	3	3
Braconidae sp.3	Br3	0	0	1	1
Braconidae sp.4	Br4	0	0	5	5
Braconidae sp.5	Br5	0	0	3	3
Formicidae					
Anoplolepis gracillipes	Fo1	20	24	0	44
Cardiocondyla emeryi	Fo2	51	0	10	61
Cardiocondyla nuda	Fo3	2	8	22	32
Hypoponera sp.1	Fo4	77	24	11	112
Hypoponera sp.2	Fo5	4	12	13	29
Meranoplus bicolor	Fo6	14	0	0	14
Monomorium destructor	Fo7	1	0	0	1

Appendix Table 1 Continued

Class/Order/ Family/Species	Abbreviation	CAS	GAP	OFS	Total
Monomorium pharaonis	Fo8	0	0	1	1
Monomorium sechellense	Fo9	64	6	41	111
Monomorium talpa	Fo10	0	3	102	105
Odotoponera denticulata	Fo11	1	0	7	8
Oligomyrmex sp.1	Fo12	0	0	5	5
Pachycondyla chinensis	Fo13	11	3	26	40
Paratrechina longicornis	Fo14	34	7	14	55
Paratrechina sp.1	Fo15	7	0	11	18
Pheidole plagiaria	Fo16	17	0	0	17
Pheidole sp.1	Fo17	11	0	0	11
Pheidologeton affinis	Fo18	18	173	83	274
Pheidologeton diversus	Fo19	78	16	2	96
Plagiolepis sp.2	Fo20	7	0	0	7
Smitristruma sp.1	Fo21	0	0	2	2
Solenopsis geminata	Fo22	68	4	101	173
Strumigenys sp.1	Fo23	2	5	0	7
Tapinoma melanocephalum	Fo24	336	21	77	434
Technomyrmex kraepelini	Fo25	18	0	0	18
Tetramorium lanuginosum	Fo26	94	5	12	111
Tetramorium bicarinatatum	Fo27	0	5	3	8
Tetramorium parvum	Fo28	5	1	39	45
Tetramorium similimum	Fo29	0	12	0	12
Tetramorium smithii	Fo30	190	0	164	354
Mutillidae					
Mutillidae sp.1	Mu1	0	0	2	2
Mutillidae sp.2	Mu2	0	0	1	1
Orthoptera					
Gryllidae					
Acheta domesticus (Linnaeus, 1758)	Gr1	3	14	11	28
Gryllus sp.1	Gr2	0	0	1	1
Tetrigidae					
Tetrigidae sp.1	Tet1	1	4	1	6
Tetrigidae sp.2	Tet2	0	2	0	2
Tetrigidae sp.3	Tet3	0	1	3	4
Tetrigidae sp.4	Tet4	0	0	2	2
Tetrigidae sp.5	Tet5	0	0	1	1
Tridacticidae					
Tridactylus thoracicus Guérin-Méneville, 1844	Tri	15	17	33	65
Psocoptera	Pso	2	4	0	6
Thysanoptera	Thy	1	10	17	28
Malacostraca					
Isopoda	IS	37	97	233	367

CAS = conventional agricultural system, GAP = good agricultural practice system, OFS = organic farming system.