BIODIVERSITAS
Volume 17, Number 2, October 2016
Pages: 746-752

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d170250

Insect pollinator diversity along a habitat quality gradient on Mount Slamet, Central Java, Indonesia

IMAM WIDHIONO♥, EMING SUDIANA, EDY TRI SUCIANTO
Faculty of Biology, Universitas Jenderal Soedirman. Jl. Dr. Soeparno No. 68, Purwokerto, Banyumas 53122, Central Java, Indonesia. Tel. +62-281-638794, Fax: +62-281-631700, ♥email: imamwidhiono@yahoo.com

Manuscript received: 28 February 2016. Revision accepted: 8 September 2016.

Abstract. *Widhiono I, Sudiana E, Sucianto ET. 2016. Insect pollinator diversity along a habitat quality gradient on Mount Slamet, Central Java, Indonesia. Biodiversitas 17: 746-752.* The diversity of wild bees and wasps in seven habitat types (natural forest, teak forest, pine forest, Agathis forest, community forest, gardens, and agricultural areas) representing the habitat quality gradient of Mount Slamet and adjacent areas in Central Java, Indonesia, was studied from April to June 2012. We examined whether habitat quality affected the diversity of wild bees and wasp pollinators. In total, 938 wild bee and wasp specimens representing 13 species of bees and 2 species of wasps were collected using kite netting. Wild bee diversity differed significantly among the habitat types ($F_{6,281} = 1.2$ $p < 0.05$). The Spearman's correlation coefficients confirmed that wild bee diversity was correlated with habitat quality ($r^2 = 0.67$ $p < 0.05$). Habitats that included all of the major wild plant species supported the highest wild bee diversity.

Keywords: Kite netting, major wild plant species, species richness, wasp, wild bee

INTRODUCTION

Mount Slamet (3,428 m asl.) is the highest mountain in Java and is located in the southwest of Central Java province. Previously, this area was covered with plantations and natural forest under the management of Perum Perhutani (The State Forest Agency). Following political and economic instability in Indonesia in 1998, a forested area on the lower portion of this mountain was converted into agricultural land dominated by vegetables crops that require insect pollinators to produce better fruits. A recent study by Widhiono and Sudiana (2015) recorded 17 insect pollinators, predominantly wild bees, visiting vegetable crops. The agricultural area is surrounded by a mosaic of other land-use types that can act as habitats for wild bees, especially forested habitat. Conversion of forested areas to agricultural habitats results in habitat simplification, which can affect the diversity and abundance of insect pollinators due to changes in wild plant diversity and abundance. These differences, in turn, affect the availability of pollen and nectar, which are vital resources for insect pollinators.

Habitat quality is usually measured as plant species richness or abundance. Plants are needed by insects for food and reproduction, and their species richness and abundance significantly affect the diversity of insect pollinators (Potts et al. 2003; Kleintjes et al. 2006; Campbell and Husband 2007). Natural and seminatural (forested) habitats are often critical to the overall species richness of insect pollinators (Hendrickx et al. 2007; Billeter et al. 2008). Wild bee species richness was found to be higher in disturbed forests than in primary forests in tropical Southeast Asia (Liow et al. 2001; Steffan-Dewenter and Tscharntke 2001; Thomas 2001). Comparative studies of a broad range of habitats along a land-use intensification gradient from primary forest to plantation forest, community forest, gardens, and agricultural areas, have generally focused on plant density or flower abundance, and to the best of our knowledge, no studies have examined local wild plant species acting as key factors in supporting the diversity of wild bees.

Furthermore, especially in Indonesia, no studies have addressed the quality of natural, semi-natural, or non-crop habitats and their relationships with insect pollinator diversity, despite the fact that wild bees are responsible for the majority of the pollination of cultivated plants in the region. Widhiono and Sudiana (2015) identified 42 species of wild plants on Mount Slamet and in adjacent areas, 24 of which are visited by wild bees and wasps. Of these 24 species, 8 species (hereafter referred to as the "major wild plant species") were visited by more than one wild bee species: *Cleome rutidosperma* (Cleomeaceae), *Borreria laevicaulis* (Rubiaceae), *Barleria elegans* (Acanthaceae), *Euphorbia heterophylla* (Euphorbiaceae), *Rubus parviflorus* (Rosaceae), *Salomonia cantoniensis* (Polygalaceae), *Tridax procumbens* (Asteraceae) and *Vero cinerea* (Asteraceae). In this study, we defined habitat quality as the species richness and the density of the major wild plant species used for food by insect pollinators. We examined whether habitat quality affects the species richness and abundance of wild bees and wasp pollinators in different habitat types on Mount Slamet, and hypothesized that the habitat types with the highest species richness and density of the major wild plant species support the highest diversity and abundance of wild bees and wasps.

MATERIALS AND METHODS

Study area

The study was conducted from April to June 2012 in the East Banyumas Forest Management Unit of the State Forest Agency (Perum Perhutani), on the southern and northern slopes of Mount Slamet, Central Java, Indonesia. The area lies at approximately 7°18’23.72”S, 109°14’06.51”E at 600-800 m asl. We surveyed seven different habitat types in our study area encompassing a range of wild plant species richness and abundance. The total size of study area was 17 ha, and the habitat types were classified as natural forest (NF, 5 ha), teak forest (TF, 2.5 ha), pine forest (PF, 2.5 ha), *Agathis* forest (2.5 ha), community forest (2.5 ha), gardens (G, 0.5 ha), and agricultural areas (Ag, 1.5 ha).

Sampling protocol

Each habitat type was divided into five random transects, each 5 m wide and 100 m long. The number of wild bees and wasps (Hymenoptera) was recorded during the morning between 6:00 a.m. and 12:00 p.m. in a standardized manner along transects. Sampling was conducted by sweep-netting in the herbaceous layers and understoreys of the plots, twice a month (total sampling six times/transect). Where possible, all bees observed were captured, and the plant visited by each bee was noted. Following each insect survey, the wild plant species richness and density were recorded in each subplot. Because some of our data were collected by nonexpert insect enthusiasts, we were limited in our taxonomic resolution. Some insects could be identified to species level with the help of a Hymenopteran taxonomist from the Indonesian Academy of Sciences, Bogor. Samples of the wild plants were stored for identification in the Plant Taxonomy Laboratory, Faculty of Biology, Universitas Jenderal Soedirman, Purwokerto, Banyumas, Central Java, Indonesia; used standard literatures for Java plants such as Backer and Bakhuizen van den Brink (1963-1968) and Steenis (1972).

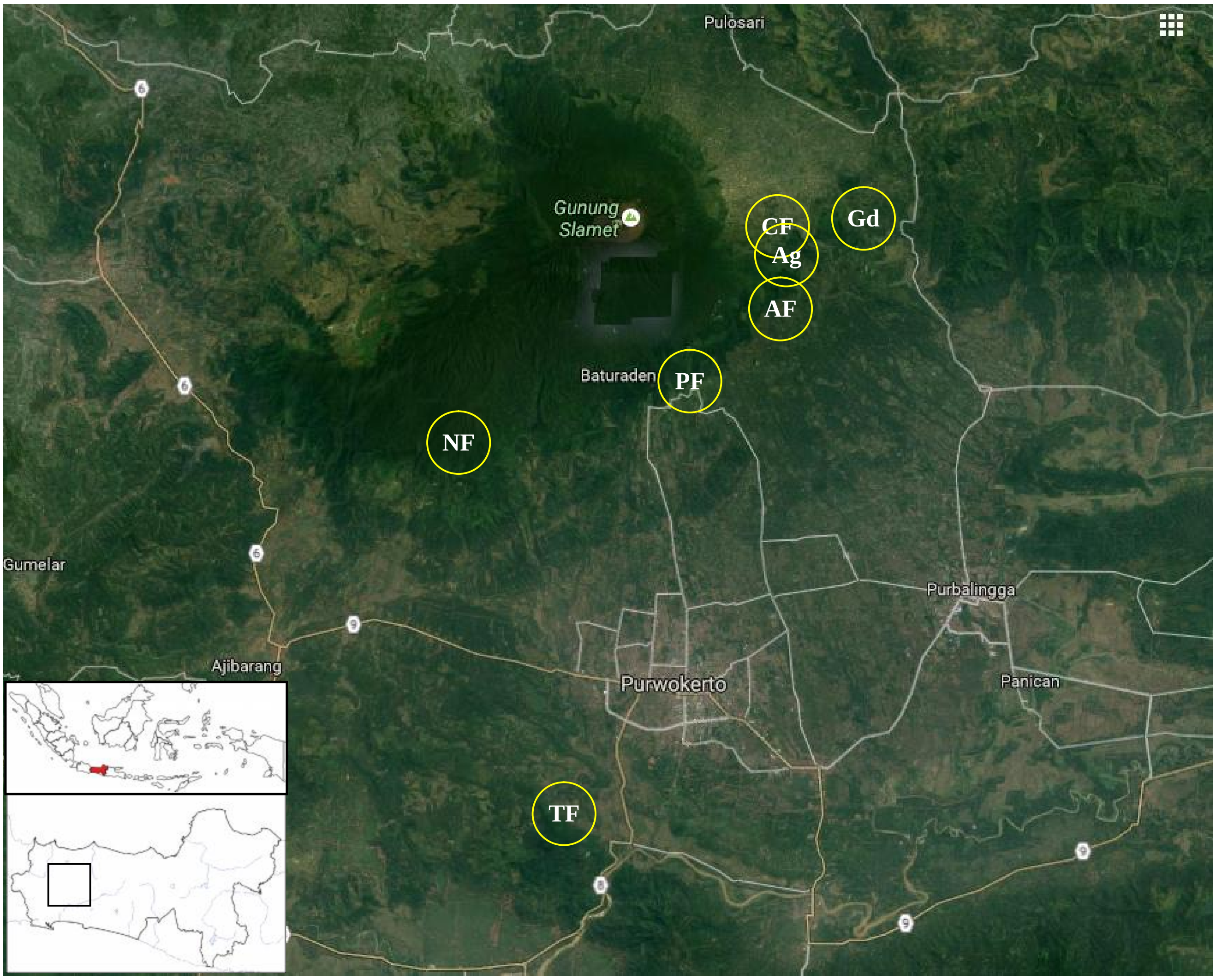


Figure 1. Study site, seven habitat types on Mount Slamet, Banyumas and Purbalingga regencies, Central Java

Table 1. Description of seven habitat types on Mount Slamet, Central Java, Indonesia

Habitat	Location	Main vegetation	Wild plant species	Wild plant densities (stdev)
Natural Forest (NF)	7°20’13.54”S, 109°08’01.06”E, 719 m asl.	19-20 tropical tree species	36 species	70.52 ± 39.88 ind/sp.
Teak Forest (TF)	7°29’11.56”S, 109°11’34.85”E, 239 m asl.	*Tectona grandis*	36 species	67.80 ± 32.88 ind/sp.
Pine Forest (PF)	7°16’52.23”S, 109°15’56.44”E, 929 m asl.	*Pinus merkusii*	27 species	42.69 ± 47.33 ind/sp.
Agathis Forest (AF)	7°17’53.19”S, 109°14’54.62”E, 834 m asl.	*Agathis dammara*	23 species	42.69 ± 47.33 ind/sp.
Community Forest (CF)	7°14’34.86”S, 109°18’12.46”E, 1081 m asl.	*Albazia cinensis*	33 species	45.69 ± 29.93 ind/sp.
Gardens (Gd)	7°14’13.11”S, 109°18’12.15”E, 954 m asl.	Ornamental plants	25 species	45.69 ± 29.93 ind/sp
Agricultural Areas(Ag)	7°15’01.12”S, 109°17’58.53”E, 954 m asl.	Cash crops	26 species	15.83 ± 22.69 ind/sp

Data analysis

To compare the overall community structure of the insect and wild plant taxa among the habitats, we calculated the accumulated species richness, total abundance, and alpha diversity (Shannon H', Simpson D, and Evenness [E]) for the seven habitats after pooling of data set. We calculated the alpha diversity using the Shannon-Wiener diversity index, a measure that takes into account the proportional abundance of each species (Margurran 1988). Comparisons of the species compositions among the different forest habitats were performed using single linkage cluster analysis based on the Bray-Curtis similarity. Diversity parameters were calculated using the Biodiversity Pro2 software (McAleece et al. 1997). We used the Spearman’s rank correlation coefficients to determine whether insect species richness and abundance were significantly correlated with wild plant diversity and abundance.

RESULTS AND DISCUSSION

Herbaceous wild plant species richness and density varied among the examined habitat types (Figure 1), ranging from 23 species in AF to 36 species in NF and CF, and from 114 individuals/100 m^2 in Ag to 507 individuals/100 m^2 in NF, respectively. The distribution, species richness, and abundance of the major wild plant species showed significant differences among the habitat types. The most abundant family was Asteraceae, with 11 species, followed by Fabaceae, with 3 species. Seven families were represented by two species each, and nine families were represented by one species each. All of the eight major wild plant species occurred in NF, TF, and CF, whereas only three of these species were found in PF and AF.

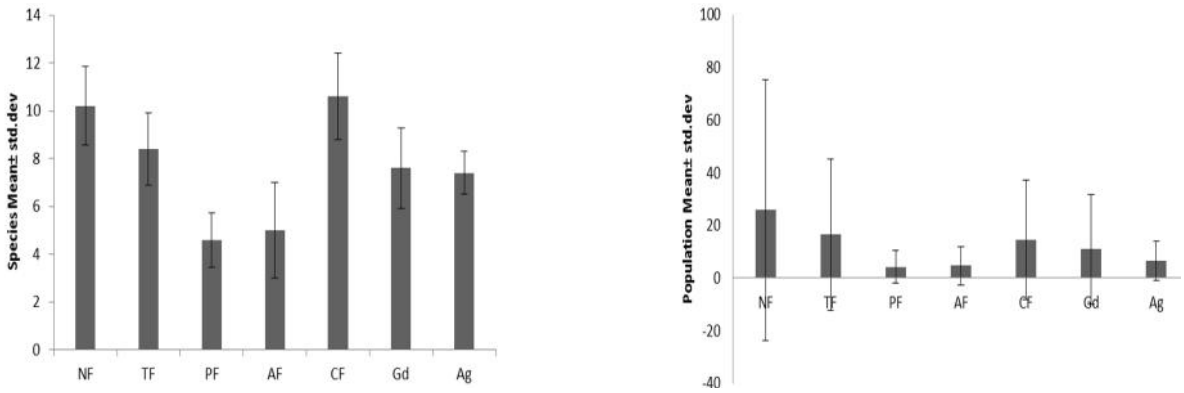
Differences in the species richness of the major wild plant species among habitats are caused by the habitat preferences of these plants. Almost all of these wild plants are abundant in sunny or slightly shaded habitats, generally corresponding to young secondary vegetation (Nwaogaranya and Mbaekwe 2015). The forest understory is a heterogeneous and dynamic habitat, within which the bulk of species contribute to ecosystem functioning and sustenance (Sharma 2013). The observed differences in plant species richness can be explained by the responses to environmental variables in the habitats. The major environmental factors that influence the growth of vegetation are sunlight, water, and nutrients, which are the primary drivers of plant species richness at the local scale (Pausas and Austin 2001). Among the forested habitats, the lowest richness of herbaceous wild plant species was found in AF and PF, in agreement with the results reported by Nahdi (2014), who observed low herbaceous species richness in PF and AF in Yogyakarta. The low abundance of wild plants in AF may due to land-management practices, including the application of fertilizer, mowing, and weed control, that lead to greater availability of nutrients, which benefits only a few plant species. The use of mowing and weed control practices to exclude outcompeted plant species changes plant species assemblages, reducing plant diversity and resulting in reduced plant species richness and an altered plant community composition (Williams et al. 2010).

Wild bee and wasp abundances differed significantly among the habitats ($F_{6,281} = 1.2$, $p < 0.05$). The highest abundance was observed in NF, with 229 individuals (24.41%), followed by CF, with 171 individuals (18.2%), Gd, with 162 individuals (17.2%), TF, with 161 individuals (17.16%), Ag, with 91 individuals (9.7 %), and AF, with 66 individuals (7.03%). The lowest abundance occurred in PF, with only 58 individuals (6.1%). From Tukey HSD test showed that CF was the best habitats comparing to all others forest types (sig-0,015 <0.05) (Table 2). The Shannon-Wiener diversity index (H') indicated that CF had the highest diversity of wild bees ($H' = 2.049$) (Table 3).

These findings are in agreement with those of Liow et al. (2001), who reported that bee abundance particularly that of Apidae, was significantly higher in CF than in other forested habitat types. However, our results were inconsistent with the findings of Hegland et al. (2009), who reported that local bee densities and diversities were highest in open land, followed by agroforestry systems, and were lowest in primary forests. Forested habitats offer nesting sites for many bee species (Klein et al. 2003; Brosi et al. 2007, 2008). This is demonstrated by the occurrence of *Apis dorsata* in only NF and TF habitats because this bee species prefers to build nests in the very tall trees found in these forest types (Starr et al. 1987; Tan 2007). Although open land provides better food resources in the herbaceous layer, bees often occur across different habitats that provide different resources (Tscharntke et al. 2005).

The intermediate abundance of wild bees observed in Gd and Ag indicates that mass-flowering crop species enhance wild plant populations, which provide floral resources for pollinators in these habitats (Steffan-Dewenter and Westpal 2008) and that the dispersal ability of wild bees limits their abundance in agricultural fields (Carvalheiro 2010). These positive effects on bee populations occur in areas where agriculture increases the heterogeneity of habitat within the range of foraging bees (Kremen et al. 2007). The fact that the highest wild bee abundance was found in NF can be explained by the correlation between herbaceous vegetation density and habitat structure in NF.

The highest species richness was recorded in CF. The vegetation structure in CF was irregular, which resulted in a diverse canopy cover with a combination of forest and open land structures. This produced higher flower density and therefore a better food supply in the understory than is available in natural habitats (Potts et al. 2003; Bruna and Ribeiro 2005), resulting in greater bee richness and density. However, this result contrasts with the findings of Winfree (2007), who reported that open-land habitats exhibited the highest bee species richness and abundance compared with agroforestry and forest habitats.



A B

Figure 1. Wild plant species (A) and Wild plant populations (B) in seven habitat types on Mount Slamet (mean ± SD)

Table 2. Total abundance of wild bees and wasps determined from a survey performed using insect nets (n = 15) in seven habitat types on Mount Slamet, Central Java, Indonesia

Family	Pollinator	Habitat type							Total	Relative abundance (%)
		NF	TF	PF	AF	CF	Gd	Ag		
Apidae	*Apis cerana*	78	50	19	21	50	66	27	311	33.1
	Apis dorsata	37	12	0	0	0	0	0	49	5.2
	Trigona laeviceps	60	47	0	0	47	43	0	197	21
	Amegilla cingulata	4	4	0	4	7	4	6	29	3
	Amegilla zonata	8	7	4	3	6	1	0	29	3
	Nomia melanderi	3	3	2	5	5	3	6	27	2.8
	Ceratina nigrolateralis	5	3	0	9	4	9	14	44	4.6
Megachilidae	*Megachile relativa*	15	16	11	11	12	6	4	75	7.9
Halictidae	*Lasioglossum malachurum*	0	0	7	0	6	11	6	30	3,.1
	Lasioglossum leucozonium	0	0	8	0	13	7	10	38	4,.05
	Ropalidia fasciata	0	0	0	3	3	7	1	14	1.4
Colletidae	*Hylaeus modestus*	2	0	0	0	0	0	0	2	0.02
Anthophoridae	*Xylocopa confusa*	0	0	0	0	11	0	12	23	2.4
Vespidae	*Delta campaniforme*	10	9	0	4	1	0	0	24	2.5
	Polistes fuscata	7	10	7	6	6	5	5	46	4.9

Table 3. Diversity parameters of wild bees in seven habitat types on Mount Slamet, Central Java

Parameter	Habitat type						
	NF	TF	PF	AF	CF	GD	AG
Species	11	10	7	9	13	11	10
Shannon H'	1.804	1.856	1.765	1.969	2.049	1.759	2.042
Simpsons (D)	0.217	0.202	0.183	0.160	0.178	0.247	0.150
Evenness (E = H'/ln s)	0.752	0.806	0.907	0.896	0.799	0.733	0.887

Our results show that CF is an important secondary habitat for wild bees (H' = 2.049). The Spearman's correlation coefficients showed that insect pollinators species richness and abundances were correlated with wild plant species richness ($r^2 = 0.67$, $p < 0.05$ and $r^2 = 0.63$, $p < 0.05$, respectively). Our results highlight the importance of wild plant species richness in the habitat for supporting wild bee species richness and abundance; however, this is only true for habitats with low species diversity, such as AF, PF, Gd, and Ag. The positive impact of wild plant richness on pollinator species richness can be explained by increased floral resource heterogeneity, which increases the attractiveness for many pollinator species seeking both single and multiple resources (Tscharntke et al. 1998; Potts et al. 2003). In forested habitats (NF and TF), we also found that wild bee diversity was affected by wild plant abundance ($r^2 = 0.68$, $p < 0.05$), supporting the hypothesis that high floral density within a habitat increases wild bee diversity because greater floral abundance means higher resource availability for pollinators. Previous studies have reported that wild plant abundance is one of two key variables structuring pollinator communities (Potts et al. 2003, 2010).

Our results were consistent with earlier studies performed by Steffan-Dewenter and Tscharntke (2001) in successional fallows and wheat fields (Holzschuh et al. 2007), where bee abundance was reported to increase with plant species richness and abundance (Buri et al. 2014). However, the results from our study are inconsistent with those of Hegland and Boeke (2006), who reported no significant effects of plant species richness on pollinator species richness.

The abundance of the major wild plant species did not affect wild bee diversity ($r^2 = 0.44$, $p < 0.05$). This finding can be explained by floral density's being more important than species richness because the availability of the main food resources (nectar and pollen) has a greater impact on the pollinators, as was reported by Hegland and Boeke (2006). Habitats with a high density of flowering plants are more attractive to pollinators than are those with a high diversity of flowering plants due to the lower travel time between multiple sparse patches in the former. Pollinators also tend to change their foraging behavior in response to flowering plant density to maximize nectar or pollen acquisition (Elliott and Irwin 2009).

Apis cerana was the most abundant and dominant species in all of the examined habitat types, with a total of 331 individuals (33.1%), followed by *Trigona laeviceps*, with 197 individuals (21.0%), whereas *Hylaeus modestus* had the lowest abundance, with only 2 individuals (0.02%). The most numerous family of pollinating insects in the investigated habitats was Apidae, with seven species, followed by Halictidae, with three species, and Vespidae, with two species. The least numerous were Megachilidae, Colletidae, and Anthophoridae, with only one species each. Only three species were found in all of the studied habitats. All of the pollinator taxa recorded in this study is categorized as generalist pollinators, i.e., they visit several plant species, and these pollinator species exhibit a wide range of floral choices and nesting requirements, which is advantageous for switching to alternative resources (Maldonado et al. 2013). Native bees, which are generally specialists and can be solitary, are present in smaller numbers in nature. Comparison of the solitary bee communities observed in this study showed that *Amegilla cingulata*, *Nomia melanderi*, *Ceratina* sp., *Lasioglossum malachurum*, *L. leucozonium*, and *Xylocopa latipes* were present in the highest numbers in artificial habitats (CF, Gd, and Ag) due to their habit of nesting in the soft mortar of building walls, whereas the genera *Apis* and *Trigona*, as well as genera of solitary bees with some tendency toward communalism (Xylocopinae) and subsocial behavior (Family Halictidae, tribes Augochlorini and Halictini), nest in pre-existing cavities in tree trunks or decomposing wood, or on the ground in banks or flat areas (Souza and Campos 2008). Multidimensional scaling supported this finding; bee communities in habitats with high wild plant species richness and abundance (NF, TF, CF, and Gd) included a wider variety of species compositions, whereas those in habitats with low wild plant species richness and abundance exhibited low species diversity. CF and Gd maintain high regional species richness due to diverse management practices and moderate disturbance intensity, which enhances floral species abundance and spatio-temporal habitat heterogeneity

The similarity of the wild bee species among the habitats based on the Bray-Curtis index ranged from 31.5% to 80.56%. We observed an 80.56% overlap between NF and TF and an 80.54% overlap between PF and AF. TF had 79% similarity with CF. These results indicate high similarity in the respective wild plant communities. Clustering of the similarities of wild bees among the habitat types showed that the wild bee community could be divided into the following three groups: NF and TF; Gd and CF; and AG, AF, and PF (Figure 2).

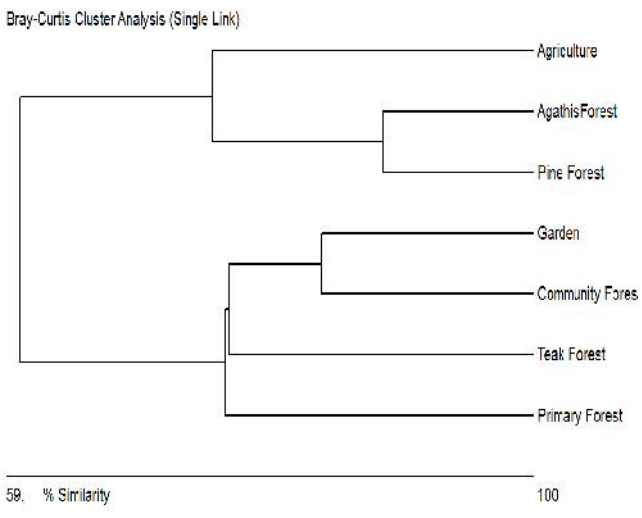


Figure 2. Similarity of wild bee species composition among habitats using Bray-Curtis analysis (single linkage)

In conclusion, the quality of the investigated habitats differed in terms of their relative contributions to wild bee diversity. The wild bee diversity in habitats with few wild plant species was strongly correlated with wild plant diversity, whereas in habitats with high wild plant species richness, flowering plant abundance was more important. The number of wild bee taxa recorded in the studied habitats showed that the diversity of wild plants species in these areas was fairly high and that the quality of the habitats in terms of plant species richness was important in maintaining pollinator diversity, both for solitary wild bee species and for eusocial wild bees.

ACKNOWLEDGEMENTS

We are grateful to Akhmad Iqbal, Totok Agung, Soewarto, and Yulia Sistina for their support in securing funding for this research, and to all of the students who assisted in collecting field data. This research was supported by a Directorate General of Higher Education Research Fellowship and funding from the Universitas Jenderal Soedirman, Purwokerto, Central Java, Indonesia. The authors declare that there are no conflicts of interest regarding the publication of this paper.

REFERENCES

Backer CA, Bakhuizen van den Brink RCJr. 1963-1968. Flora of Java (Spermatophytes only). P. Noordhoff, Groningen

Billeter R, Liira J, Bailey D, Bugter R, P. Arens P, Augenstein I, Aviron S, Baudry J, Bukacek R, Burel F, Cerny M, De Blust G, De Cock R, Diekötter T, Dietz H, Dirksen J, Dormann C, Durka W, Frenzel M, Hamersky R, Hendrickx F, Herzog F, Klotz S, Koolstra B, Lausch A, Le Coeur D, Maelfait JP, Opdam P, Roubalova M, Schermann A, Schermann N, Schmidt T, Schweiger O, Smulders MJM, Speelmans M, Simova P, Verboom J, W van Wingerden W, Zobel M, Edwards PJ. 2008. Indicators for biodiversity in agricultural landscapes: a pan-European study. J Appl Ecol 45: 141-150.

Brosi B J, Daily G C, Ehrlich P R. 2007. Bee community shifts with landscape context in tropical countryside. Ecol Appl 17: 418-430.

Brosi B J, Daily G C, Shih T M, Oviedo F, Durán G. 2008. The effects of forest fragmentation on bee communities in tropical countryside. J Appl Ecol 45: 773-783.

Bruna EM, Ribeiro MBN. 2005. The compensatory responses of an understory herb to experimental damage are habitat-dependent. Am J Bot 92: 2101-2106.

Buri P, Humbert YY, Arlettaz R. 2014. Promoting pollinating insects in intensive agricultural matrices: field-scale experimental manipulation of hay-meadow mowing regimes and its effects on bees. PloS one 9: e85635. DOI: 10.1371/journal.pone.0085635.

Campbell LG, Husband BC. 2007. Small populations are mate-poor but pollinator-rich in a rare, self-incompatible plant, *Hymenoxys herbacea* (Asteraceae). New Phytol 174: 915-925.

Carvalheiro LG, Seymour CL, Veldtman R, Nicolson SW. 2010. Pollination services decline with distance from natural habitat even in biodiversity-rich areas. J Appl Ecol 47: 810-820.

Elliott SE, Irwin RE. 2009. Effects of flowering plant density on pollinator visitation, pollen receipt, and seed production *Indelphinium barbeyi* (Ranunculaceae). Am J Bot 96: 912-919.

Hegland SJ, Boeke L. 2006. Relationships between the density and diversity of floral resources and flower visitor activity in a temperate grassland community. Ecol Entomol 31: 532-538.

Hegland SJ, Nielson A, Lazaro A, Bjekers AL, Totland O. 2009. How does climate warming affect plant-pollinator interactions? Ecol Lett 12: 184-195.

Hendrickx F, Maelfait JP, Van Wingerden W, Schweiger O, Speelmans M, Aviron S, Augenstein I, Billeter R, Bailey D, Bukacek R, Burel F, Diekötter T, Dirksen J, Herzog F, Liira J, Roubalova M, Vandomme V, Bugter R. 2007. How landscape structure, land-use intensity and habitat diversity affect components of total arthropod diversity in agricultural landscapes. J Appl Ecol 44: 340-351.

Holzschuh A, Steffan-Dewenter I, Kleijn D, Tscharntke T. 2007. Diversity of flower-visiting bees in cereal fields: effects of farming system, landscape composition and regional context. J Appl Ecol 44: 41-49.

Klein AM, Steffan-Dewenter I, Tscharntke T. 2003. Flower visitation and fruit set of *Coffea canephora* in relation to local and regional agroforestry management. J Appl Ecol 40: 837-845.

Kleintjes PK, Fettig SM, Vanoverbeke NB. 2006. Variable response of butterflies and vegetation to elk herbivory: an exclosure experiment in ponderosa pine and aspen-mixed conifer forests southwestern naturalist. J Lepidopterists Soc 52: 1-14.

Kremen C, Williams NM, Aizen MA, Gemmill-Herren B, LeBuhn G, Minckley R, Packer L, Potts SG, Roulston T, Steffan-Dewenter I, Vázquez DP, Winfree R, Adams L, Crone EE, Greenleaf SS, Keitt TH, Klein AM, Regetz J, Ricketts TH. 2007. Pollination and other ecosystem services produced by mobile organisms: a conceptual framework for the effects of land-use change. Ecol Lett 10: 299-314.

Liow LH, Sodhi NS, Elmqvist T. 2001. Bee diversity along a disturbance gradient in tropical lowland forests of South-East Asia. J Appl Ecol 38: 180-192.

Maldonado MB, Lomascolo SB, Vazquez DP. 2013. The importance of pollinator generalization and abundance for the reproductive success of a generalist plant. PloS One 8: e75482. DOI: 10.1371/journal.pone.0075482.

Margurran EA. 1988. Ecological Diversity and its Measurement. 1st ed. Chapman and Hall. London.

McAleece N, Gage JDG, Lambshead PJD, Paterson GLJ. 1997. BioDiversity Professional statistics analysis software. Jointly developed by the Scottish Association for Marine Science and the Natural History Museum, London.

Nahdi MS. 2014. The distribution and abundance of plant species under the shade of *Pinus merkusii*, *Acacia auriculiformis* and *Eucalyptus alba* in Giri Gama Mandiri forest, Yogyakarta. Jurnal Natur Indonesia 16: 33-41. [Indonesian]

Nwaogaranya UP, Mbaekwe EI. 2015. Some aspects of the biology of *Vernonia cinerea* (Linn.) Less. Int J Sci Res Publ 5 (9):.

Pausas JP, Austin MP. 2001. Patterns of plant species richness in relation to different environments: an appraisal. J Veg Sci 12: 153-166

Potts SG, Biesmeijer JC, Kremen C, Neumann P, Schweiger O, Kunin WE. 2010. Global pollinator declines: trends, impacts and drivers. Trends Ecol Evol 25: 345-353.

Potts SG, Vulliamy B, Dafni A, Ne'eman G, Willmer P. 2003. Linking bees and flowers: how do floral communities structure pollinator communities? Ecol 84: 2628-2642.

Sharma N. 2013. Dynamics and characterization of herbaceous vegetation in three forest communities in a subtropical dry deciduous forest in Jammu, Jammu and Kashmir. Int J Sci Res 2319-7064.

Souza DE, Campos ME. 2008. Composition and diversity of bees (Hymenoptera) attracted by moericke traps in an agricultural area in Rio Claro, state of São Paulo, Brasil Iheringia. Série Zoologia 98: 236-243.

Starr CK, Schmidt PJ, Schmidt J. 1987. Nest-site preferences of giant honey bee, *Apis dorsata* (Hymenopetra: Apidae), in Borneo. Pan-Pacific Entomol 63: 37-42.

Steenis CGGJ van. 1972. The Mountain Flora of Java. E.J. Brill, Leiden.

Steffan-Dewenter I, Tscharntke T. 2001. Succession of bee communities on fallows. Ecography 24: 83-93.

Steffan-Dewenter I, Westpal C. 2008. The interplay of pollinator diversity, pollination services and landscape change. J Appl Ecol 45: 737-741.

Tan NQ. 2007. Biology of *Apis dorsata* in Vietnam. Apidologie 38: 221-229.

Thomas JA, Bourn NAD, Clarke RT, Stewart KE, Simcox D, Pearman GS, Curtis R, Goodger B. 2001. The quality and isolation of habitat patches both determine where butterflies persist in fragmented landscapes. Proc R Soc London Ser B-Biol Sci 268: 1791-1796.

Tscharntke T, Gathmann A, Steffan-Dewenter I. 1998. Bioindication using trap-nesting bees and wasps and their natural enemies: community structure and interactions. J Appl Ecol 35: 708-719.

Tscharntke T, Klein AM, Kruess A, Steffan-Dewenter I, Thies C. 2005. Landscape perspectives on agricultural intensification and biodiversity-ecosystem service management. Ecol Lett 8: 857-874.
Widhiono I, Sudiana E. 2015. The role of wild plants in the conservation of pollinating insects of the Order Hymenoptera. Pros Sem Nas Masy Biodiv Indon 1: 1586-1590. [Indonesian]
Williams NM, Crone EE, Roulston TH, Minckley RL, Packer I, Potts SG. 2010. Ecological and life-history traits predict bee species responses to environmental disturbances. Biol Conserv 143: 2280-2291.
Winfree R, Griswold T, Kremen C. 2007. Effects of human disturbance on bee communities in a forested ecosystem. Conserv Biol 21: 213-223.