PEER REVIEW

A6

LEMBAR
HASIL PENILAIAN SEJAWAT SEBIDANG ATAU PEER REVIEW
KARYA ILMIAH : JURNAL ILMIAH

Judul Jurnal Ilmiah (Artikel) : Contribution of Plantation Forest on Wild Bees (Hymenoptera:Apoidea) Polinators Conservation in Mount Slamet, Central Java, Indonesia.

Penulis Jurnal Ilmiah *) : 1 Imam Widhiono (*nama pengusul dicetak tebal)
2 Eming Sudiana
3 Edy Yani

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Contribution of Plantation Forest on Wild Bees (Hymenoptera: Apoidea) Pollinators Conservation in Mount Slamet, Central Java, Indonesia

✉**Imam Widhiono, Eming Sudiana, Edi Yani**

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Abstract

Wild bee pollinators (Hymenoptera : Apiade) diversity and abundance were studied in three types of plantation forest on Mt. Slamet (Central Java Province, Indonesia). The aims of the research was to know the diversity and abundance of wild bee pollinators and to determine the possibility of plantation forest contribution on wild bees conservation. Sampling has been done at three stands: a pine forest (PF, with *Pinus merkusii*), an Agathis forest (AF, with *Agathis damara*) and a community forest (CF, with *Albizia falctaria*). Each habitat was divided into 5 line transect (100 x 5 m) and sweep nets were used to collect the wild bee samples. Sampling was done eah month from April to August 2015. The diversity of wild bees was high (12 species in 9 genera; members of the Apidae (7 species were dominant). The most abundant species across the forests were *Apis cerana* (343 individuals; 25.5% of total), *Trigona laeviceps* (195 individuals; 14.5%), and *Megachille relativa* (165 individuals; 12.3%). Measurements of species diversity (*H'*), species evenness (*E*), habitat similarity (*Ss*) and species richness indicated that the wild bee species diversity in the region was relatively high (*H'* = 1.275) to (*H'* = 1.730); (E= 0.870) to (E = 0.93). The result showed that the diversity of wild bees in three different plantation forest habitats on Mt. Slamet were similar and can be concluded that plantation forest types were important for pollinator conservation, and an appropriate future preservation strategy should include of the areas of all plantation forest types.

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INTRODUCTION

The bee fauna of the Indomalayan regions is the poorest (89 genera) in the world compared to the other regions, because the higest bee diversity was in arid temperates regions (Corlett, 2004), however bees are recognized as important pollinators for both crops and wild plants worldwide (Klein et al., 2008; Potts et al., 2010). Most bees are solitary but many nest communally and eusocial species with female castes are found in the families Halictidae and Apidae (Corlett, 2004).

Almost all of the tropical wild bees depend on forest habitat for food and nesting resouces for survival and reproduction. On the other hand, the importance of forest habitat to bees may not be the same in tropical areas. The abundance and species richness of wildbees negatively affected by habitat loss and fragmentation (Winfree *et al.*, 2010), but according to Taki et al., (2013) only extreme habitat loss have negatively impacts the abundance and species richness of wild bees. Moderate disturbances in forests, including cultivated plantations, may help maintain pollinator abundance and diversity by expanding the cover of herbaceous plant species, thereby increasing nectar and pollen availability (Winfree et al., 2007). The low density of overstorey trees in plantation stands allows sunlight to penetrate through to the forest floor, where it supports the growth of diverse understory taxa that maintain abundant populations of many bee species.

Mt. Slamet, the highest mountain on the island of Java, is located in the southwestern sector of Central Java Province. Plantation forests in Slamet Mountain typically dominated by one or a few tree species, (*Pinus merkusii, Agathis damara or Albizia falfactaria*) are grown as homogenous age and size. Since 2001, pine forests and Agathis forests in the region only in harvesting the sap and do not do logging for timber production (Perhutani, 2001). Timber production has focused on Community forest with Ablizia tree and harvested on relatively short rotations,bordering these plantations are also planted, but they are not managed by the State Forest Agency.These plantations forests was becoming increasingly dominant components of the landscape, but little is known about their value for general biodiversity conservation, and even less about their value for the preservation of wild bee (Hymenoptera: Apoidea) diversity and abundance, which are the most important angiosperm pollinators . The plantation forests are believed to contribute to wild bee conservation (Hartley, 2002) because they provide essential resources for the establishment and development of sustainable pollinator populations, such as nesting sites, shelter and food supplies (Kremen et al., 2004: Klein et al., 2008). Wild bee pollinators generally depend on the flowers of native plants (Mandelik et al., 2012). Many bees require large numbers of flowers to provide nectar and pollen, but they also need variety in the flowering plants available to them to sustain them through the year (Williams et al., 2010). However, the plant species and plant flowering phenologies in plantation forest habitats differ from the natural forest. Hence, in comparison with the native forest, plantation forest have significant temporal shifts in the quantity and diversity of nectar and pollen resources (Jongjitvimol & Petchsri, 2015; Williams et al., 2010).

Differences in plantation forest type may affect the diversity and abundance of wild bee pollinators (Brosi et al., 2008). In Indonesia the potential of plantation forest habitats for wild bee conservation is very important , because, the wild bees are responsible for most of the plant pollination in cultivated fields adjacent to the platation forests area. However research on wildbee pollinators diversity in plantation forest is very rare. Widhiono and Sudiana (2016) found that forest edges is an important factors as a source of wild bee pollinators in three crops plantation. The purposes of the research was to know the diversity and abundance of wild bee on three plantation forest types. For the future, the result of the research will postulated to conserve wild bee diversity and abundance based on plantation forests

METHODS

The research sites were on the northern slope of Mt. Slamet, close to the Karangreja and Purbalingga regencies of Central Java Province, Indonesia. Three study sites with different types of plantation forest were selected: pine forest (PF), Agathis forest (AF), and community forest (CF), all of which were located at altitudes of 880-929 m above sea level (a.s.l.) (Table 1). The areal extent of the sampling sites in each of the plantation forests was 25 ha.

The three plantation forests were sampled monthly in the period April-August 2015. In each plantation, we laid out five 100 × 5-m belt transects that included the widest range of habitat conditions. We used the standard sweep net procedures of Brosi et al., (2008) to sample the bees. We planned to compare wild bee diversities in the lower vegetation strata; thus, we perfor-

Table 1. Habitat types, elevations, and vegetation types at the three plantation forest types

Habitat type	Location	Altitude (m a.s.l.)	Vegetation type
Pine Forest (PF)	7°16'52.23"S, 109°15',56.44"E	929	*Pinus merkusii*
Agathis Forest (AF)	7°16'53.19"S, 109°15'56.62"E	834	*Agathis dammara*
Community Forest (CF)	7°16'52.23"S 109°15'56.44"E	880	*Alibizia falcataria*

Legend: m. a.s.l.= meter above sea level

med net sweeps in the aboveground vegetation. During each sampling session, five members of the field team (one person per transect) aerially netted bees over 30-min periods. Bees on the flowers and in flight were collected individually with the sweep net. To reduce collection bias, bees were netted only along the transect routes. Sampling was performed in the mornings (07:00-09:00 local time) on fine days. After the completion of bee collection, the field teams measured flowering plant resources along the transects in 10 randomly deployed quadrats (1 × 1 m). In each quadrat, we recorded the species and numbers of flowering individuals of herbaceous plants. Bee species were identified by the Indonesian Institute of Science. Voucher specimens are held at the Entomology Laboratory, Faculty of Biology, Jenderal Soedirman University, Indonesia. Plant specimens were identified by a plant taxonomist at the same institute.

We compiled a list of wild bee and herbaceous plant species for each of the three plantation forests. We calculated the Shannon-Wiener index *H'* based on the numbers of bee species within a site and the relative abundance of each bee species as an indicator of bee diversity (Margurran, 1998). Comparisons of bee diversity between sites were based on the magnitude of the diversity indices. To compare relative abundances or individual distributions among the communities, we calculated the Evenness index *E*. The dominant species in each area was determined using Simpson's index *D*. Sorensen's similarity coefficient *S* was used as a similarity index to compare the species similarities between pairs of communities. All data analysis was done by the help of BD Pro software (McNelly et al., 1997). We used ANOVA and LSD tests to compare overall bee abundance and species richness among habitats. We conducted detailed spatiotemporal analyses of the species richness and abundance of wild bees and floral resources across the plantation forest types. We analyzed bee richness and abundance patterns using a linear mixed-model analysis executed with SPSS 19.0 software. Habitat type and sampling date were main factors in the modeling procedure; species richness and the abundance of blooming plants in each sample plot were covariates, and species richness and the abundance of wild bees were dependent factors. Individual subjects in the repeated measures analysis were the dates of sampling for each of the five transects (25 replicates in total).

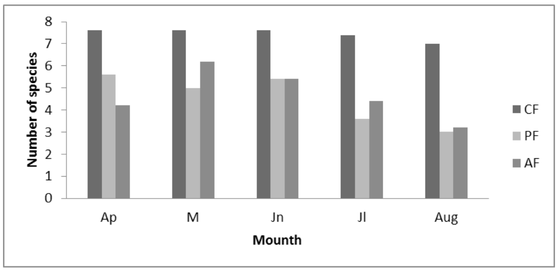
RESULTS AND DISCUSSION

We collected 1340 individuals of 12 wild bee pollinator species in the three forest types over 75 sampling days. These belonged to nine genera in five families: Apidae (seven species), Halictidae (three species), Anthophoridae (one species), Colectidae (one species), and Megachilidae (one species) (Table 2). We detected no significant difference in total species richness among habitats. We collected 11, 10, and 10 species in the PF, CF, and AF sites, respectively (see Table 1 for site codes). Measured bee species richness values did not differ markedly among forest sites. The bee fauna was relatively speciose and dominated by members of the family Apidae, which are the primary pollinators of wild plants and agricultural crops in this region (Widhiono and Sudiana, 2016). We found seven species of Apidae (Table 2). Among these, only *Apis dorsata* was very rare. These finding because of the habitat condition in platation forest not suitable nesting site. Forest habitats of Java commonly have seven species of bees. In protected forest (Gunung Halimun National Park) West Java, Kahono, (2000) studied wild bee and wasp, where they found 19 species of insects, 10 of which were members of the order Hymenoptera. In the apple plantations of Malang (East Java) 15 species in seven insect orders were found visiting the plant ground cover (Purwatiningsih *et al.,* 2012). Those three location was signifantly different in vegetation structure.

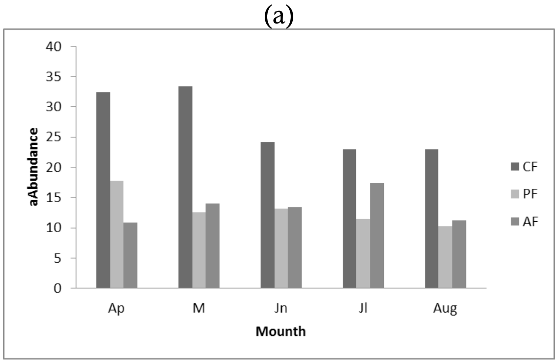
Twelve species of insect pollinators at recent study sites was sufficient abundance to guarantee pollination success of flowering plants in the region. Nevertheless, the number of wild insects in the plantation forests was slightly lower than that in agricultural lands, where as many as 17 species occur. Furthermore, the number of species found on Mt. Slamet was relatively low in comparison with collections in four Thai forest types, where 22 species of insect pollinators were collected (Jongjitvimol & Petchsri, 2015), and forest plantations on Sulawesi, where 55 species were found (Hoehn et al., 2010). This differencies due to the species of three stands, in recent study sites, three plant species dominated by pine, agathis and albizia which resulting less flowering hebaceus plant in ground cover (Jongjitvimol & Petchsri, 2015).

The mean number of species caught per month was significantly different among sites (F =10,76 p = 0.001). We calculated the average number of species collected per month in each habitat as a measure of the stability in the number of species over time (Fig. 1a). In CF, the number of species was very stable, ranging from a high of 7.6 ± 0.25 in April to a low of 7.2 ± 0.25 in August. In PF, the species number was highest in May (6.2 ± 0.99) and lowest in August (3.2 ± 0.99). In AF, the numbers were highest in April (5.6 ± 0.77) and lowest in August (3.0 ± 0.77). Across sites, the species numbers declined from rainy to dry seasons, but the shift was significant in only PF (F =10,76 , p < 0.05). The species richness and abundance of insect pollinators at study sites tended to decline from April to August. Thus, values were higher in the rainy season than in the dry season. We suspect that these changes were related to shifts in food resource availability. The percentage of native vegetation ground cover on the forest floor influences the richness and abundance of wild bees. Our findings on seasonal shifts are in agreement with earlier studies (Samnergard et al., 2015; Greenleaf et al., 2007 ; Patrício-Roberto & Campos, 2014).

Most of the bee species collected (10) were found in all three sites. *Apis dorsata* was found only in PF; *Trigona laeviceps* was absent from AF, *Ceratina nigrolateralis* was not collected in PF, and *Hyaleus modestus* was not found in CF.



(a)



(b)

Figure 1. Changes in the species richness (a) and abundance (b) of wild bees from rainy to dry seasons at three plantation types in Indonesia.

The most abundant species across the fo-

Table 2. List of wild bee families, species, and abundances in three plantation forest types on Mount Slamet.

Family	Species	Community forest	Agathis forest	Pine forest	Total abundance	Proportional abundance (%)
Apidae	*Apis cerana*	165	75	103	343	25.59
	Apis dorsata	0	0	3	3	0.2
	Trigona laeviceps	184	0	11	195	14.5
	Megachile relativa	60	57	48	165	12.3
	Amegilla cingulata	35	24	16	75	5.59
	Amegilla zonata	30	37	20	87	6.49
	Ceratina nigrolateralis	20	36	0	56	4.1
Halictidae	*Nomia melandri*	27	33	21	81	6.0
Anthophoridae	*Hylaeus modestus*	0	8	12	20	1.4
Colectidae	*Lasioglossum malachurum*	35	32	38	105	7.85
	Lasioglossum leucozonium	62	15	40	117	8.7
	Xylocopa confusa	62	17	14	93	6.94
		680	334	326	1340	

rests were *Apis cerana* (343 individuals; 25.5% of total), *Trigona laeviceps* (195 individuals; 14.5%), and *Megachille relativa* (165 individuals; 12.3%) The least abundant species was *Apis dorsata* (Table 2). More bees (680) were collected in CF than in PF (334) or AF (326); these differences among sites were significant (F = 3,64; p < 0.001). Bee abundances varied significantly among months in CF (F = 3,64; p = 0.022) and PF (F = 4,58; p = 0.009), but not in AF (F = 1,03; p = 0.411) (Figure 1b).

The species diversity (Shannon-Wiener index, *H'*), species evenness (*E*), and dominance (*S*, Simpson's index) were relatively low in all forest types (Table 2). CF had the highest species diversity (*H'* = 1.730); PF had the lowest (*H'* = 1.275). These data were congruent with the number of bee species in each forest type. *E* was highest in AF (E = 0.93) and lowest in CF (E= 0.870) (Table 3).

The environmental factors differed little among the sites, which were located in the same landscape. However, the abundance of flowers, the number of flowering plants, canopy cover, *H'*, and *S* differed among sites. At CF, species richness was strongly correlated with the number of flowers (r = 0.97). At PF, the number of flowers was correlated with the number of species of insect pollinators (r = 0.97), their abundance (r = 0.80), and *H'* (r = 0.91). At AF, the number of flowers was correlated with species richness (r = 0.91) and *H'* (r = 0.90).

The species richness of bees was very similar among the forest sites, but bee abundance differed significantly, probably because of differences in the number of flowers available, which is related to canopy cover. These findings are congruent with previous studies (Ricketts 2004; Gardner 2009) that found relationships between the total number of flowers and bee abundance. Nevert-

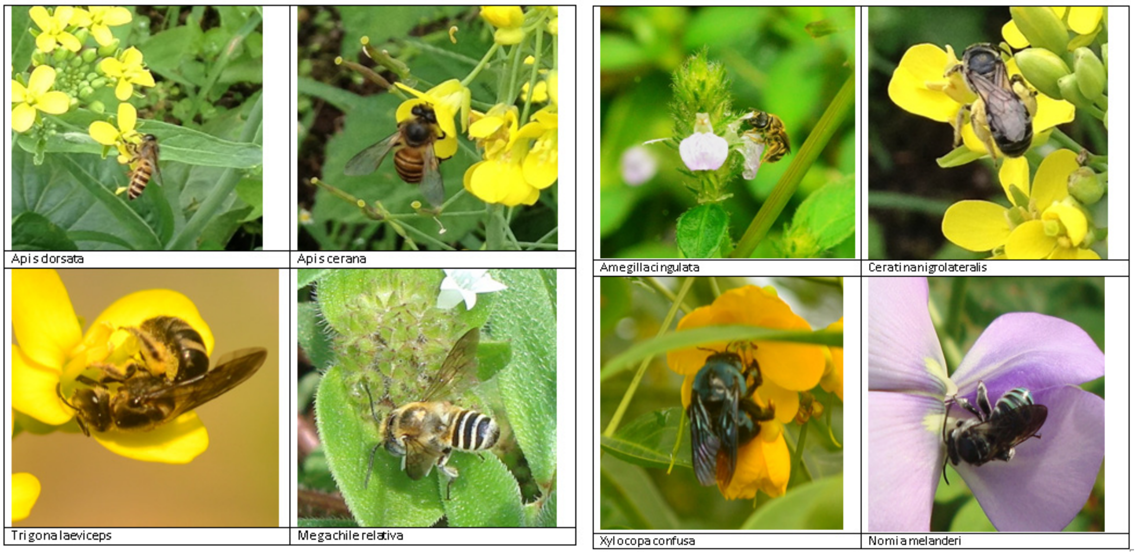


Figure 2. Wildbee in plantation forest

Table 3. Parameters measured in three plantation forest types.

Parameter	Community Forest					Pine Forest					Agathis Forest				
Month	April	May	Jun	Jul	Aug	April	May	Jun	Jul	Aug	April	May	Jun	Jul	Aug
S (number of species)	7.6	7.6	7.6	7.4	7	5.6	5	5.4	3.6	3	4.2	6.2	5.4	4.4	3.2
H' (Shannon-Wienner index	1.68	1.72	1.79	1.82	1.66	1.53	1.39	1.53	1.14	0.9	1.27	1.71	1.56	1.29	1.08
E (Evennes)	0.83	0.85	0.9	0.9118	0.862	0.91	0.87	0.93	0.91	0.88	0.92	0.95	0.93	0.92	0.93
Flowers (ind/m^2)	34.2	33.4	28.6	28.6	28.6	30	28.2	26.6	16.6	14	20.4	24	24	20.4	13.2
Wild plants (ind/m^2)	7	8.8	6.4	6.4	5.6	5.4	7.6	5	4	3.2	3.8	7.4	7.4	3.8	3.6
Daily temperature (°C)	30.2	31.8	30.2	29.6	29.4	30.8	30.4	30.8	28.4	28.2	32.2	29.4	30.2	32.2	28.8

heless, we were surprised to find more bees in CF than in the other two sites because AF and PF were relatively stable and had been subjected to little human disturbance. Bee diversity in habitats that have been modified by human activities may depend on the abundance of nesting resources and natural habitats provided by nearby forests, including plantation forests (Steffan-Dewenter *et al.,* 2002). Sorensen's similarity coefficient calculations showed that the bee species composition was influenced by forest type. Bee species compositions were most similar between PF and AF (*S* = 0.88); all *S* values were >0.5 (Figure 3)

The high abundance of wild bees in CF may have been related to habitat heterogeneity. Importantly, the canopy cover in CF was lower than that at other sites, allowing more light to penetrate to the forest floor, thereby encouraging flowering in herbaceous plants. The old, stable forests in PF and AF had fewer flowers. Our observations contradicted those of Williams *et al.* (2010) who found more bee species in rarely disturbed habitats. However, the response of wild bees to disturbance strongly depends on the species.

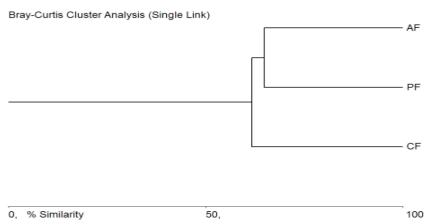


Figure 3. Similarities in bee species composition among forest types.

The new finding of the research was that three types of plantation forest have quite high diversity and abundance of wild bees pollinator, and suprisingly community forest have more insect pollinator species than agathis forest and pine forest. Furthermore this finding can be used as basic information for insect pollinator conservation strategy to supporting sustainable agriculture programm

CONCLUSSION

In conclusion, wild bee diversity and abundance in the three different plantation forest types on Mt. Slamet qiute high and supported similar species complements of wild bees. Thus, an appropriate strategy for conserving pollinator species should include expansion of the habitats provided by plantation forest types.

ACKNOWLEDGMENTS

We thank to Akhmad Iqbal, Soewarto, and Yulia Sistina for supporting this research, and all of our students for assistance in collecting field data. The work was supported by the University of Jenderal Soedirman Purwokerto, Central Java, Indonesia (Contract No. 1251/UN.23.X/PN/2015)

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TURNITIN

Contribution of Plantation Forest on Wild Bees (Hymenoptera: Apoidea) Pollinators Conservation in Mount Slamet, Central Java, Indonesia

by Eming Sudiana

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Contribution of Plantation Forest on Wild Bees (Hymenoptera: Apoidea) Pollinators Conservation in Mount Slamet, Central Java, Indonesia

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Abstract

Wild bee pollinators (Hymenoptera : Apiade) diversity and abundance were studied in three types of plantation forest on Mt. Slamet (Central Java Province, Indonesia). The aims of the research was to know the diversity and abundance of wild bee pollinators and to determine the possibility of plantation forest contribution on wild bees conservation. Sampling has been done at three stands: a pine forest (PF, with *Pinus merkusii*), an Agathis forest (AF, with *Agathis damara*) and a community forest (CF, with *Albizia falctaria*). Each habitat was divided into 5 line transect (100 x 5 m) and sweep nets were used to collect the wild bee samples. Sampling was done eah month from April to August 2015. The diversity of wild bees was high (12 species in 9 genera; members of the Apidae (7 species were dominant). The most abundant species across the forests were *Apis cerana* (343 individuals; 25.5% of total), *Trigona laeviceps* (195 individuals; 14.5%), and *Megachille relativa* (165 individuals; 12.3%). Measurements of species diversity (*H'*), species evenness (*E*), habitat similarity (*Ss*) and species richness indicated that the wild bee species diversity in the region was relatively high (*H'* = 1.275) to (*H'* = 1.730); (E= 0.870) to (E = 0.93). The result showed that the diversity of wild bees in three different plantation forest habitats on Mt. Slamet were similar and can be concluded that plantation forest types were important for pollinator conservation, and an appropriate future preservation strategy should include of the areas of all plantation forest types.

How to Cite

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INTRODUCTION

The bee fauna of the Indomalayan regions is the poorest (89 genera) in the world compared to the other regions, because the higest bee diversity was in the temperates regions (Corlett, 2004), however bees are recognized as important pollinators for both crops and wild plants world-wide (Klein et al., 2008; Potts et al., 2010). Most bees are solitary but many nest communally and eusocial species with female castes are found in the families Halictidae and Apidae (Corlett, 2004).

Almost all of the tropical wild bees depend on forest habitat for food and nesting resouces for survival and reproduction. On the other hand, the importance of forest habitat to bees may not be the same in tropical areas. The abundance and species richness of wildbees negatively affected by habitat loss and fragmentation (Winfree *et al.*, 2010), but according to Taki et al., (2013) only extreme habitat loss have negatively impacts the abundance and species richness of wild bees. Moderate disturbances in forests, including cultivated plantations, may help maintain pollinator abundance and diversity by expanding the cover of herbaceous plant species, thereby increasing nectar and pollen availability (Winfree et al., 2007). The low density of overstorey trees in plantation stands allows sunlight to penetrate through to the forest floor, where it supports the growth of diverse understory taxa that maintain abundant populations of many bee species.

Mt. Slamet, the highest mountain on the island of Java, is located in the southwestern sector of Central Java Province. Plantation forests in Slamet Mountain typically dominated by one or a few tree species, (*Pinus merkusii, Agathis damara or Albizia falfactaria*) are grown as homogenous age and size. Since 2001, pine forests and Agathis forests in the region only in harvesting the sap and do not do logging for timber production (Perhutani, 2001). Timber production has focused on Community forest with Ablizia tree and harvested on relatively short rotations,bordering these plantations are also planted, but they are not managed by the State Forest Agency.These plantations forests was becoming increasingly dominant components of the landscape, but little is known about their value for general biodiversity conservation, and even less about their value for the preservation of wild bee (Hymenoptera: Apoidea) diversity and abundance, which are the most important angiosperm pollinators . The plantation forests are believed to contribute to wild bee conservation (Hartley, 2002) because they provide essential resources for the establishment and development of sustainable pollinator populations, such as nesting sites, shelter and food supplies (Kremen et al., 2004: Klein et al., 2008). Wild bee pollinators generally depend on the flowers of native plants (Mandelik et al., 2012). Many bees require large numbers of flowers to provide nectar and pollen, but they also need variety in the flowering plants available to them to sustain them through the year (Williams et al., 2010). However, the plant species and plant flowering phenologies in plantation forest habitats differ from the natural forest. Hence, in comparison with the native forest, plantation forest have significant temporal shifts in the quantity and diversity of nectar and pollen resources (Jongjitvimol & Petchsri, 2015; Williams et al., 2010).

Differences in plantation forest type may affect the diversity and abundance of wild bee pollinators (Brosi et al., 2008). In Indonesia the potential of plantation forest habitats for wild bee conservation is very important , because, the wild bees are responsible for most of the plant pollination in cultivated fields adjacent to the platation forests area. However research on wildbee pollinators diversity in plantation forest is very rare. Widhiono and Sudiana (2016) found that forest edges is an important factors as a source of wild bee pollinators in three crops plantation. The purposes of the research was to know the diversity and abundance of wild bee on three plantation forest types. For the future, the result of the research will postulated to conserve wild bee diversity and abundance based on plantation forests

METHODS

The research sites were on the northern slope of Mt. Slamet, close to the Karangreja and Purbalingga regencies of Central Java Province, Indonesia. Three study sites with different types of plantation forest were selected: pine forest (PF), Agathis forest (AF), and community forest (CF), all of which were located at altitudes of 880-929 m above sea level (a.s.l.) (Table 1). The areal extent of the sampling sites in each of the plantation forests was 25 ha.

The three plantation forests were sampled monthly in the period April-August 2015. In each plantation, we laid out five 100 × 5-m belt transects that included the widest range of habitat conditions. We used the standard sweep net procedures of Brosi et al., (2008) to sample the bees. We planned to compare wild bee diversities in the lower vegetation strata; thus, we perfor-

Table 1. Habitat types, elevations, and vegetation types at the three plantation forest types

Habitat type	Location	Altitude (m a.s.l.)	Vegetation type
Pine Forest (PF)	7°16'52.23"S, 109°15',56.44"E	929	*Pinus merkusii*
Agathis Forest (AF)	7°16'53.19"S, 109°15'56.62"E	834	*Agathis dammara*
Community Forest (CF)	7°16'52.23"S 109°15'56.44"E	880	*Alibizia falcataria*

Legend: m. a.s.l.= meter above sea level

med net sweeps in the aboveground vegetation. During each sampling session, five members of the field team (one person per transect) aerially netted bees over 30-min periods. Bees on the flowers and in flight were collected individually with the sweep net. To reduce collection bias, bees were netted only along the transect routes. Sampling was performed in the mornings (07:00-09:00 local time) on fine days. After the completion of bee collection, the field teams measured flowering plant resources along the transects in 10 randomly deployed quadrats (1 × 1 m). In each quadrat, we recorded the species and numbers of flowering individuals of herbaceous plants. Bee species were identified by the Indonesian Institute of Science. Voucher specimens are held at the Entomology Laboratory, Faculty of Biology, Jenderal Soedirman University, Indonesia. Plant specimens were identified by a plant taxonomist at the same institute.

We compiled a list of wild bee and herbaceous plant species for each of the three plantation forest. We calculated the Shannon-Wiener index *H'* based on the numbers of bee species within a site and the relative abundance of each bee species as an indicator of bee diversity (Margurran, 1998). Comparisons of bee diversity between sites were based on the magnitude of the diversity indices. To compare relative abundances or individual distributions among the communities, we calculated the Evenness index *E*. The dominant species in each area was determined using Simpson's index *D*. Sorensen's similarity coefficient *S* was used as a similarity index to compare the species similarities between pairs of communities. All data analysis was done by the help of BD Pro software (McNelly et al., 1997). We used ANOVA and LSD tests to compare overall bee abundance and species richness among habitats. We conducted detailed spatiotemporal analyses of the species richness and abundance of wild bees and floral resources across the plantation forest types. We analyzed bee richness and abundance patterns using a linear mixed-model analysis executed with SPSS 19.0 software. Habitat type and sampling date were main factors in the modeling procedure; species richness and the abundance of blooming plants in each sample plot were covariates, and species richness and the abundance of wild bees were dependent factors. Individual subjects in the repeated measures analysis were the dates of sampling for each of the five transects (25 replicates in total).

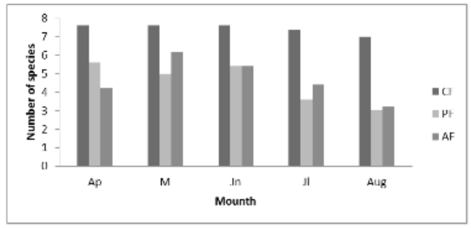
RESULTS AND DISCUSSION

We collected 1340 individuals of 12 wild bee pollinator species in the three forest types over 75 sampling days. These belonged to nine genera in five families: Apidae (seven species), Halictidae (three species), Anthophoridae (one species), Colectidae (one species), and Megachilidae (one species) (Table 2). We detected no significant difference in total species richness among habitats. We collected 11, 10, and 10 species in the PF, CF, and AF sites, respectively (see Table 1 for site codes). Measured bee species richness values did not differ markedly among forest sites. The bee fauna was relatively speciose and dominated by members of the family Apidae, which are the primary pollinators of wild plants and agricultural crops in this region (Widhiono and Sudiana, 2016). We found seven species of Apidae (Table 2). Among these, only *Apis dorsata* was very rare. These finding because of the habitat condition in platation forest not suitable nesting site. Forest habitats of Java commonly have seven species of bees. In protected forest (Gunung Halimun National Park) West Java, Kahono, (2000) studied wild bee and wasp, where they found 19 species of insects, 10 of which were members of the order Hymenoptera. In the apple plantations of Malang (East Java) 15 species in seven insect orders were found visiting the plant ground cover (Purwatiningsih *et al.*, 2012). Those three location was signifantly different in vegetation structure.

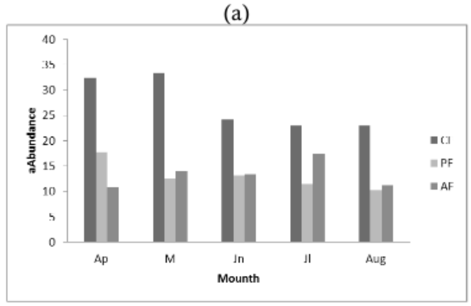
Twelve species of insect pollinators at recent study sites was sufficient abundance to guarantee pollination success of flowering plants in the region. Nevertheless, the number of wild insects in the plantation forests was slightly lower than that in agricultural lands, where as many as 17 species occur. Furthermore, the number of species found on Mt. Slamet was relatively low in comparison with collections in four Thai forest types, where 22 species of insect pollinators were collected (Jongjitvimol & Petchsri, 2015), and forest plantations on Sulawesi, where 55 species were found (Hoehn et al., 2010). This differencies due to the species of three stands, in recent study sites, three plant species dominated by pine, agathis and albizia which resulting less flowering hebaceus plant in ground cover (Jongjitvimol & Petchsri, 2015).

The mean number of species caught per month was significantly different among sites (F =10,76 p = 0.001). We calculated the average number of species collected per month in each habitat as a measure of the stability in the number of species over time (Fig. 1a). In CF, the number of species was very stable, ranging from a high of 7.6 ± 0.25 in April to a low of 7.2 ± 0.25 in August. In PF, the species number was highest in May (6.2 ± 0.99) and lowest in August (3.2 ± 0.99). In AF, the numbers were highest in April (5.6 ± 0.77) and lowest in August (3.0 ± 0.77). Across sites, the species numbers declined from rainy to dry seasons, but the shift was significant in only PF (F =10,76 , $p < 0.05$). The species richness and abundance of insect pollinators at study sites tended to decline from April to August. Thus, values were higher in the rainy season than in the dry season. We suspect that these changes were related to shifts in food resource availability. The percentage of native vegetation ground cover on the forest floor influences the richness and abundance of wild bees. Our findings on seasonal shifts are in agreement with earlier studies (Samnergard et al., 2015; Greenleaf et al., 2007 ; Patrício-Roberto & Campos, 2014).

Most of the bee species collected (10) were found in all three sites. *Apis dorsata* was found only in PF; *Trigona laeviceps* was absent from AF, *Ceratina nigrolateralis* was not collected in PF, and *Hyaleus modestus* was not found in CF.



(a)



(b)

Figure 1. Changes in the species richness (a) and abundance (b) of wild bees from rainy to dry seasons at three plantation types in Indonesia.

The most abundant species across the fo-

Table 2. List of wild bee families, species, and abundances in three plantation forest types on Mount Slamet.

Family	Species	Community forest	Agathis forest	Pine forest	Total abundance	Proportional abundance (%)
Apidae	*Apis cerana*	165	75	103	343	25.59
	Apis dorsata	0	0	3	3	0.2
	Trigona laeviceps	184	0	11	195	14.5
	Megachile relativa	60	57	48	165	12.3
	Amegilla cingulata	35	24	16	75	5.59
	Amegilla zonata	30	37	20	87	6.49
	Ceratina nigrolateralis	20	36	0	56	4.1
Halictidae	*Nomia melandri*	27	33	21	81	6.0
Anthophoridae	*Hylaeus modestus*	0	8	12	20	1.4
Colectidae	*Lasioglossum malachurum*	35	32	38	105	7.85
	Lasioglossum leucozonium	62	15	40	117	8.7
	Xylocopa confusa	62	17	14	93	6.94
		680	334	326	1340	

rests were *Apis cerana* (343 individuals; 25.5% of total), *Trigona laeviceps* (195 individuals; 14.5%), and *Megachille relativa* (165 individuals; 12.3%) The least abundant species was *Apis dorsata* (Table 2). More bees (680) were collected in CF than in PF (334) or AF (326); these differences among sites were significant ($F = 3,64$; $p < 0.001$). Bee abundances varied significantly among months in CF ($F = 3,64$; $p = 0.022$) and PF ($F = 4,58$; $p = 0.009$), but not in AF ($F = 1,03$; $p = 0.411$) (Figure 1b).

The species diversity (Shannon-Wiener index, *H'*), species evenness (*E*), and dominance (*S*, Simpson's index) were relatively low in all forest types (Table 2). CF had the highest species diversity ($H' = 1.730$); PF had the lowest ($H' = 1.275$). These data were congruent with the number of bee species in each forest type. *E* was highest in AF ($E = 0.93$) and lowest in CF ($E= 0.870$) (Table 3).

The environmental factors differed little among the sites, which were located in the same landscape. However, the abundance of flowers, the number of flowering plants, canopy cover, *H'*, and *S* differed among sites. At CF, species richness was strongly correlated with the number of flowers (r = 0.97). At PF, the number of flowers was correlated with the number of species of insect pollinators (r = 0.97), their abundance (r = 0.80), and *H'* (r = 0.91). At AF, the number of flowers was correlated with species richness (r = 0.91) and *H'* (r = 0.90).

The species richness of bees was very similar among the forest sites, but bee abundance differed significantly, probably because of differences in the number of flowers available, which is related to canopy cover. These findings are congruent with previous studies (Ricketts 2004; Gardner 2009) that found relationships between the total number of flowers and bee abundance. Nevert-

Figure 2. Wildbee in plantation forest

Table 3. Parameters measured in three plantation forest types.

Parameter	Community Forest					Pine Forest					Agathis Forest				
Month	April	May	Jun	Jul	Aug	April	May	Jun	Jul	Aug	April	May	Jun	Jul	Aug
S (number of species)	7.6	7.6	7.6	7.4	7	5.6	5	5.4	3.6	3	4.2	6.2	5.4	4.4	3.2
H' (Shannon-Wienner index	1.68	1.72	1.79	1.82	1.66	1.53	1.39	1.53	1.14	0.9	1.27	1.71	1.56	1.29	1.08
E (Evennes)	0.83	0.85	0.9	0.9118	0.862	0.91	0.87	0.93	0.91	0.88	0.92	0.95	0.93	0.92	0.93
Flowers (ind/m^2)	34.2	33.4	28.6	28.6	28.6	30	28.2	26.6	16.6	14	20.4	24	24	20.4	13.2
Wild plants (ind/m^2)	7	8.8	6.4	6.4	5.6	5.4	7.6	5	4	3.2	3.8	7.4	7.4	3.8	3.6
Daily temperature (°C)	30.2	31.8	30.2	29.6	29.4	30.8	30.4	30.8	28.4	28.2	32.2	29.4	30.2	32.2	28.8

heless, we were surprised to find more bees in CF than in the other two sites because AF and PF were relatively stable and had been subjected to little human disturbance. Bee diversity in habitats that have been modified by human activities may depend on the abundance of nesting resources and natural habitats provided by nearby forests, including plantation forests (Steffan-Dewenter *et al.,* 2002). Sorensen's similarity coefficient calculations showed that the bee species composition was influenced by forest type. Bee species compositions were most similar between PF and AF (S = 0.88); all S values were >0.5 (Figure 3)

The high abundance of wild bees in CF may have been related to habitat heterogeneity. Importantly, the canopy cover in CF was lower than that at other sites, allowing more light to penetrate to the forest floor, thereby encouraging flowering in herbaceous plants. The old, stable forests in PF and AF had fewer flowers. Our observations contradicted those of Williams *et al.* (2010) who found more bee species in rarely disturbed habitats. However, the response of wild bees to disturbance strongly depends on the species.

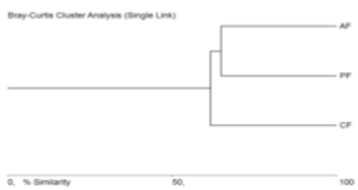


Figure 3. Similarities in bee species composition among forest types.

The new finding of the research was that three types of plantation forest have quite high diversity and abundance of wild bees pollinator, and suprisingly community forest have more insect pollinator species than agathis forest and pine forest. Furthermore this finding can be used as basic information for insect pollinator conservation strategy to supporting sustainable agriculture programm

CONCLUSSION

In conclusion, wild bee diversity and abundance in the three different plantation forest types on Mt. Slamet qiute high and supported similar species complements of wild bees. Thus, an appropriate strategy for conserving pollinator species should include expansion of the habitats provided by plantation forest types.

ACKNOWLEDGMENTS

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