

Utilization of the Stingless Bee (*Trigona* sp.) as a Natural Pollinator in Rubber (*Hevea brasiliensis*) Agroforestry Program of PT Pertamina EP Sangatta Field, East Kalimantan, Indonesia

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Abstract— Rubber (*Hevea brasiliensis*) is an agroforestry commodity that provides ecological services, such as carbon uptake, erosion control, and habitat provision. However, its small, densely clustered flowers limit effective pollination by wild insects, so seed set and latex productivity often remain below their potential levels. This study reports a biodiversity conservation program carried out by PT Pertamina EP Sangatta Field, East Kalimantan, Indonesia, which introduced stingless bee (*Trigona* sp.) colonies in collaboration with partner farmer group, Trigona Reborn Group, as a natural pollinator for rubber trees grown under an agroforestry system together with citrus, mango, and papaya as companion crops. A suction-based honey-harvesting tool (Bee-Sap) was introduced to collect honey without damaging the comb, thereby allowing the colony to function as a pollinator. Monitoring conducted from January to June 2025 recorded the conservation of 250 rubber trees, an estimated colony population of 13,000 *Trigona* sp. individuals, and a program biodiversity index (H') of 0.90. The results indicate that the small body size and floral constancy behavior of *Trigona* sp. allow it to effectively reach the small rubber flowers, supporting cross-pollination, while the partnership also provides an additional income source for the farmer group through honey and propolis production.

Keywords— Agroforestry, Biodiversity conservation, *Hevea brasiliensis*, Natural pollinator, Stingless bee, *Trigona* sp.

I. INTRODUCTION

PT Pertamina EP Sangatta Field is a company engaged in oil and gas exploration and production that is committed to environmental conservation and community empowerment in its operational area. As part of this commitment, the company manages a conservation area for rubber (*Hevea brasiliensis*) developed under an agroforestry system, in which forestry species are combined with agricultural crops on the same land unit to increase land productivity, maintain ecosystem sustainability, and generate economic, ecological, and social benefits. Rubber-based agroforestry provides broader ecosystem services than rubber monoculture, including higher carbon storage and stronger support for biodiversity indicators (Perdomo Diaz et al., 2025).

Globally, *Hevea brasiliensis* is listed as Least Concern on the IUCN Red List (Fabriani & Hills, 2020). However, this status does not automatically guarantee the long-term sustainability of rubber populations, as regeneration still depends on the quality of the surrounding ecosystem, including the availability of effective pollinators. As a long-lived tree species, rubber also provides important ecological functions, such as carbon absorption, reduction of greenhouse gas emissions, prevention of soil erosion, maintenance of microclimate humidity, and provision of habitat for various flora and fauna (Singh et al., 2021; Liu et al., 2016).

Rubber is a cross-pollinated plant, and fruit and seed formation depend strongly on the presence of an effective pollinator (Li et al., 2022). In practice, however, natural pollination of *Hevea brasiliensis* by wild insects tends to be nonoptimal because the flowers are small, densely arranged, and clustered, which limits the ability of larger insects to reach the stigma. A study on insect pollinators in oil palm, rubber, and jungle-rubber land uses in Sumatra also found that pollinator communities in rubber plantations are commonly dominated by small carpenter bees rather than large-bodied bees, and that a *Trigona* sp. nest was found inside a rubber tree trunk (Siregar et al., 2016). Nonoptimal pollination reduces the number of seeds available for generative propagation and constrains natural regeneration, which increases the risk that a rubber stand becomes dominated by older, less productive trees.

At the same time, the company's CSR partner group in Sangkima Selatan Village, Trigona Reborn Group, maintains stingless bee (*Trigona* sp.) colonies, but has faced declining colony productivity because the number and variety of flowers available around the settlement area are limited. Honey harvesting that is still performed manually also tends to damage the comb, which disturbs the colony and reduces its long-term sustainability (Md Zaki & Abd Razak, 2018).

Pollinators play an important economic and ecological role. Approximately 75% of global food crops depend at least partly on animal pollination (Potts et al., 2016). Among insect pollinators, stingless bees have been reported as effective pollinators for various crops because of their small body size and floral constancy behavior, which increases the efficiency of cross-pollination and improves fruit and seed formation (Atmowidi et al., 2022; Wongsu et al., 2023). Due to these conditions, PT Pertamina EP Sangatta Field has proposed a solution by employing *Trigona* sp. colonies from the partner group as natural pollinators for rubber flowers. The program design was complemented by a honey-harvesting device that was specifically engineered to maintain the sustainability of the colonies. This study aims to evaluate the effectiveness of the stingless bee (*Trigona* sp.) colonies as natural pollinators within rubber (*Hevea brasiliensis*) agroforestry systems, assessed based on: (1) the number of rubber trees and bee colonies successfully conserved, (2) the biodiversity index of the conservation area, and (3) a comparison of pollination conditions before and after the intervention.

II. MATERIAL AND METHODS

2.1 Study Area and Program Design

This program was conducted in 2025 in the rubber (*Hevea brasiliensis*) agroforestry conservation area of PT Pertamina EP Sangatta Field in East Kalimantan, Indonesia. Within the agroforestry system, rubber trees are planted together with other crops, namely citrus (*Citrus sinensis*), mango (*Mangifera indica*), and papaya (*Carica papaya* L.), which serve as additional food sources for pollinating insects and help maintain a more balanced micro-ecosystem. The program was conducted in partnership with Trigona Reborn Group, a community group from the company's CSR-assisted village that cultivates *Trigona* sp. colonies.

2.2 Program Intervention

The main intervention was the introduction of *Trigona* sp. colonies belonging to the partner farmer group into the rubber agroforestry area to act as a natural pollinator. This approach makes use of the bee's small body size, which corresponds to the small and clustered morphology of the rubber flower, together with its floral constancy behavior, that is, the tendency to visit flowers of the same species within a single foraging trip, which increases the probability of effective cross-pollination. As a complementary intervention, a honey-harvesting tool (Bee-Sap) that works on a suction principle was applied so that nectar and honey could be extracted without damaging the comb. This tool was intended to reduce colony stress during harvesting and maintain colony population so that the bees could continue functioning as pollinators.

2.3 Data Collection

Monitoring was conducted from January to June 2025. An absolute counting method was used to record the cumulative number of rubber trees benefiting from *Trigona* sp. pollination and successfully conserved, together with the cumulative colony population and the number of companion-crop individuals in the conservation area. The biodiversity condition of the conservation area was calculated using the Shannon-Wiener diversity index (H'), which accounts for both the number of species present and the evenness of individuals among those species (Shannon & Weaver, 1949). The index was calculated separately for the flora and fauna recorded in the reclamation/conservation area using Equation (1).

$$H' = -\sum (p_i \ln p_i) \quad (1)$$

where p_i is the proportional abundance of species i , calculated as $p_i = n_i / N$, where n_i is the number of individuals of species i , and N is the total number of individuals of all species recorded in the conservation area (Shannon & Weaver, 1949).

Following this framework, an H' value below 1 is generally interpreted as low diversity dominated by very few species, a value between 1 and 3 as moderate diversity, and a value above 3 as high diversity. The overall program biodiversity index was obtained by combining the flora and fauna index values for the same monitoring period, providing a single indicator of the ecological condition of the conservation area that can be tracked from one monitoring period to the next.

III. RESULT AND DISCUSSION

3.1 Results

3.1.1 Individuals Conserved in the Agroforestry Area

Field documentation of the conservation area is presented in Figure 1, showing the physical condition of the components summarized in Table 1. The *Hevea brasiliensis* stand was recorded as a mature rubber planting arranged under the agroforestry pattern together with the companion crops described above. The *Trigona* sp. colony belonging to Trigona Reborn Group was documented in its hive box positioned within the rubber stand to allow direct foraging access to the surrounding flowers.



FIGURE 1: Field documentation of the rubber agroforestry conservation program at PT Pertamina EP Sangatta Field: (a) *Hevea brasiliensis* stand under the agroforestry system; (b) *Trigona* sp. colony housed in a wooden hive box; (c) application of the Bee-Sap non-destructive honey-harvesting tool.

Table 1 presents the cumulative number of individuals conserved in the agroforestry area up to June 2025, the target rubber trees, companion crops used for ecological support, and the introduced *Trigona* sp. colony. Table 1 shows that the target species of the program, rubber (*Hevea brasiliensis*), reached a cumulative total of 250 conserved trees, the largest single count among all plant species recorded and equivalent to approximately 71.6% of the 349 total plant individuals monitored across the five plant categories in the table. The companion crops occupied the remaining share, led by the grass/cover crop category with 54 individuals (15.5% of the plant total), followed by papaya with 30 individuals (8.6%), citrus with 10 individuals (2.9%), and mango with 5 individuals (1.4%). This distribution indicates that, in terms of individual count, the area is still dominated by the rubber stand itself, while the companion crops function as a smaller, supporting layer rather than an equally large component of the planting. The *Trigona* sp. colony was reported with a cumulative population of 13,000 individuals as of June 2025.

TABLE 1
CUMULATIVE NUMBER OF INDIVIDUALS CONSERVED IN THE AGROFORESTRY AREA (JUNE 2025)

No.	Local Name	Scientific Name	Total (2025)	Unit
1	Rubber	<i>Hevea brasiliensis</i>	250	Trees
2	Grass (cover crop)	<i>Panicum</i> sp.	54	Individuals
3	Citrus	<i>Citrus sinensis</i>	10	Trees
4	Mango	<i>Mangifera indica</i>	5	Trees
5	Papaya	<i>Carica papaya</i>	30	Trees
6	Stingless bee (kelulut)	<i>Trigona</i> sp.	13,000	Individuals

3.1.2 Biodiversity Index of the Conservation Area

Table 2 shows a flora diversity index of $H' = 0.90$. This value is classified as a low-diversity condition, consistent with a planting scheme that is still dominated by a single species (rubber) rather than an evenly distributed mix of species. The fauna diversity index for the same monitoring period was reported as $H' = 0.00$, reflecting that fauna monitoring in this cycle centered on the single introduced pollinator taxon, *Trigona* sp., rather than a multi-species fauna survey.

TABLE 2
BIODIVERSITY INDEX OF THE CONSERVATION AREA (2025)

IKH – Reclamation Area	2025
Flora Diversity Index (H')	0.9
Fauna Diversity Index (H')	0
Program Biodiversity Index	0.9

3.1.3 Condition Observed Before and After the Program

Prior to the program, field observations revealed that the pollination of *Hevea brasiliensis* in the conservation area was carried out only by wild insects without a managed pollinator. The flowers of the rubber tree were observed to be small, densely arranged, and clustered, a morphology that restricted the ability of these insects to contact the stigma. As rubber is a cross-pollinated plant, this constraint was reflected in seedlings with lower vigor, which were more susceptible to disease, and latex yields that remained below their potential. Field records from Trigona Reborn Group showed a less productive *Trigona* sp. colony prior to the program, a condition linked to the limited availability of flowers in the settlement area that served as the main source of nectar and pollen for bees. Honey harvesting is still carried out manually, which damages the comb and further weakens the sustainability of the colonies in the surrounding areas (Figure 2).

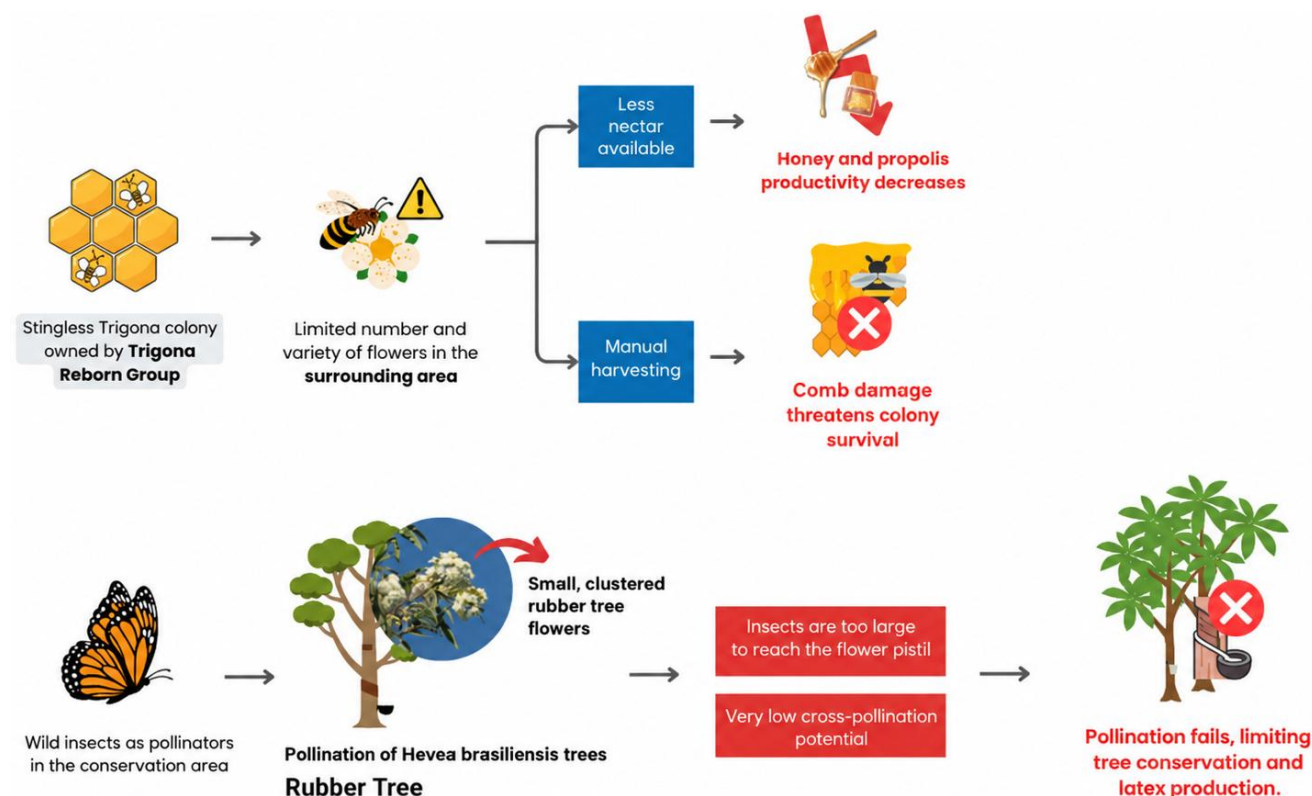


FIGURE 2: Schematic conditions before the program included limited floral resources and manual harvesting constraining the partner colony, and small, clustered rubber flowers limiting wild insect pollination.

After the program was implemented, *Trigona* sp. colonies belonging to Trigona Reborn Group were introduced into the rubber agroforestry area, and the Bee-Sap harvesting tool was put into use. Field monitoring recorded a cumulative conservation of 250 rubber trees, together with a *Trigona* sp. population of 13,000 individuals (Table 1), and a program biodiversity index of 0.90 (Table 2) for the January–June 2025 period. Figure 3 summarizes the post-program conditions, including the pathway from colony introduction to increased honey and propolis production, and the pathway from improved cross-pollination to tree conservation.

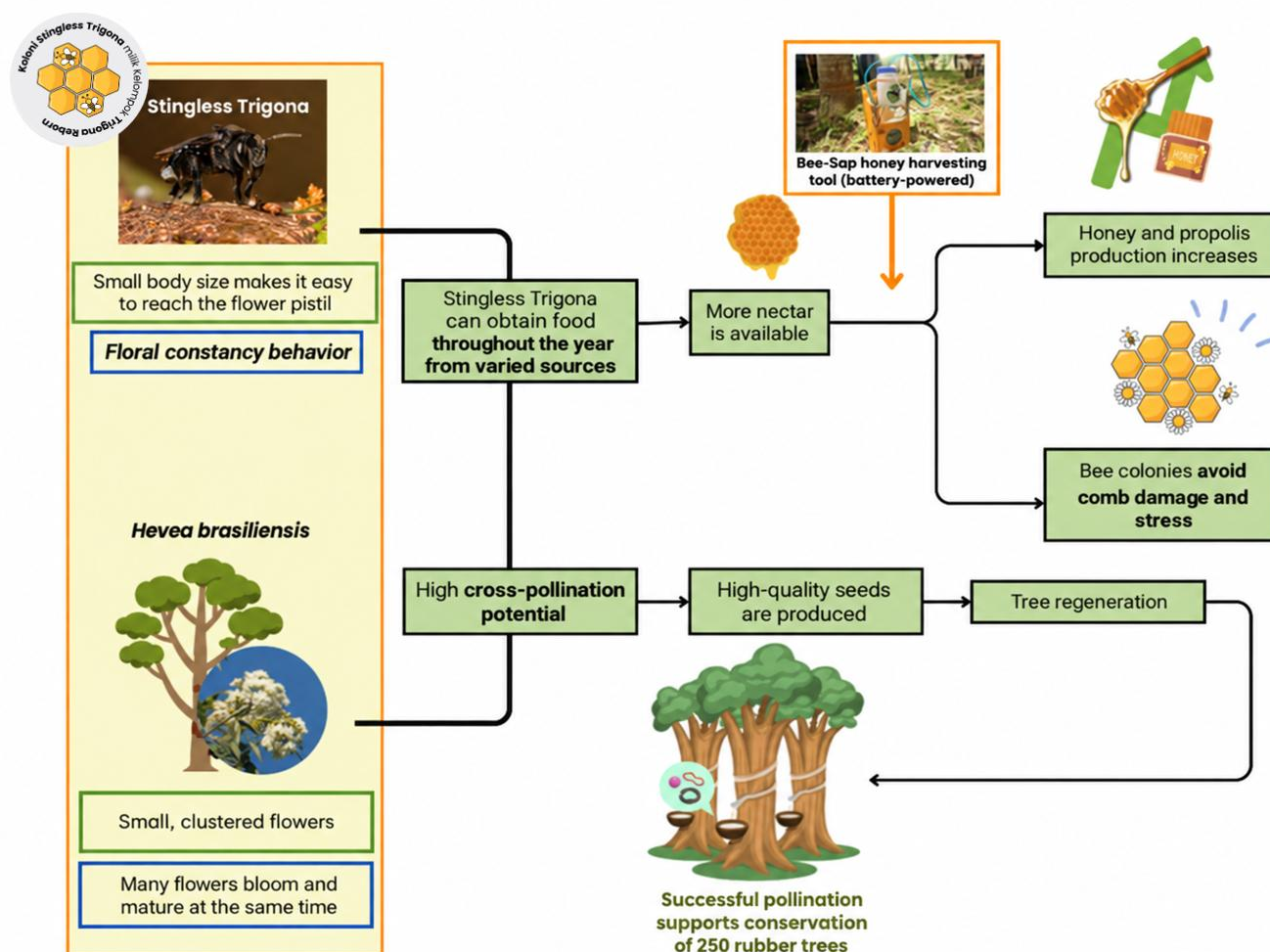


FIGURE 3: Schematic conditions after the program: *Trigona* sp. gains wider access to floral resources and is harvested non-destructively, whereas improved cross-pollination supports seed quality, tree regeneration, and conservation of 250 rubber trees.

3.2 Discussion

3.2.1 Mechanism of *Trigona* sp. as a Natural Pollinator of *Hevea brasiliensis*

The 250 conserved rubber trees and 13,000-individual *Trigona* sp. colony reported in Table 1 can be explained by the match between the bee's morphology and the rubber flower's structure. *Trigona* sp. was selected as the natural pollinator because its small body size matches the morphology of the *Hevea brasiliensis* flower. This allows the bee to enter the narrow floral opening, make contact with the anther and stigma, and carry pollen between flowers effectively (Ramadani et al., 2021; Md Zaki & Abd Razak, 2018). The abundant pollen produced by rubber flowers is then used by *Trigona* sp. as a main food resource for larval growth, colony health, and honey reserves, which is consistent with the increase in colony population implied by the program's monitoring data.

Trigona sp. also shows floral constancy, in which there is a tendency to visit flowers of the same species within one foraging period. This behavior increases the likelihood of cross-pollination between rubber flowers, producing higher-quality seeds and

supporting tree regeneration, and is consistent with reports that stingless bees improve fruit and seed formation in other crops through the same mechanism (Atmowidi et al., 2022; Wongsu et al., 2023). Because rubber is a cross-pollinated species, this mechanism offers a plausible biological pathway from pollinator intervention to improved seed set and tree conservation, as shown in Figure 2, although the present monitoring design, being an applied field program rather than a controlled experiment, does not itself isolate pollination from other contributing factors.

3.2.2 Role of Companion Planting in Supporting the Agroforestry System

The comparatively small share of companion crop individuals shown in Table 1 (citrus, mango, and papaya together making up less than 13% of the total plant) is consistent with their intended role as a supporting rather than a dominant planting layer. PT Pertamina EP Sangatta Field planted these companion crops to support the agroforestry system, help balance the ecosystem, and protect the soil, providing supplementary nectar and pollen sources alongside rubber flowers. With this combination, rubber productivity is supported both ecologically and economically, while a more sustainable agroforestry ecosystem is established, a pattern broadly consistent with reports that diversified rubber-based agroforestry systems support stronger biodiversity outcomes than rubber grown as a monoculture (Perdomo Diaz et al., 2025).

This program represents a sub-system-level change with an environmental impact classified as species protection through ecological engineering. The 250 conserved rubber trees, 13,000-individual *Trigona* sp. colony, and program biodiversity index of 0.90 (Tables 1 and 2) indicate that the program supports the preservation of the native habitat around the working area and contributes to the conservation of other flora and fauna in the surrounding landscape, including habitat within the Kutai National Park ecosystem, even though the flora index value is low. The PT Pertamina EP Sangatta Field conservation program was conducted in collaboration with Trigona Reborn Group and Kutai National Park. Trigona Reborn Group was responsible for bee cultivation and the commercial use of honey as an economically valuable product, while Kutai National Park supported biodiversity conservation and the preservation of stingless bee habitat. This collaboration not only increased rubber productivity through natural pollination but also strengthened conservation efforts and community empowerment around the working area, consistent with the broader recognition that pollinator-dependent economic value extends well beyond the immediate crop being pollinated (Potts et al., 2016).

IV. CONCLUSION

The integration of *Trigona* sp. stingless bee colonies as natural pollinators, proposed by the PT Pertamina EP Sangatta Field conservation program in collaboration with Trigona Reborn Group, supported the conservation of 250 rubber trees and an estimated colony of 13,000 individuals, with a program biodiversity index of 0.90. The small body size and floral constancy behavior of *Trigona* sp. allowed it to effectively access the small, clustered rubber flowers, while the non-destructive harvesting tool helped maintain colony sustainability. The program also generated economic benefits for the partner farmer group through increased honey and propolis production. As this program was implemented as an applied field intervention rather than a controlled experiment, further systematic monitoring, such as direct measurement of seed set, latex yield, colony population dynamics, and a multi-species fauna survey to complement the current flora-based index, is recommended to strengthen the quantitative evidence for the pollination effect reported here.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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