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Name	Counterpart	Title
Yeni A. Mulyani, Tri Ananda Nur Ikhsan, Azru Azhar, Gusthi Ayu Permatasari, Rizky Nazarreta, Windra Priawandiputra, Damayanti Buchori	**B09**	Evaluating biodiversity and ecosystem services in the Biodiversity Enrichment Experiment (BEE)

Research summary

Massive rainforest transformation into cash crop plantations has resulted in the loss of critical habitat for many plants and animals of the forests. Maintaining biodiversity with agroforestry that combines crop production with trees is one way to overcome the transformation impacts. Integrating between maintaining crop production and planting various trees has been proposed as a strategy to satisfy livelihood needs while increasing biodiversity and ecological functions. EFForTS established a large-scale and long-term biodiversity enrichment experiment using six different tree species planted in oil palm plantation sites, bird and insects survey in experimental enrichment oil palm plantation are very important to be studied. By investigating their diversity and functional role over time in the enrichment experimental in oil palm plantations, we could understand the influence of plant composition structure changing in a large monoculture plantation. A bird survey was previously conducted a year after the enrichment plots were established and based on our present result, the number of bird species remained relatively the same (20–21 species) but with changes in bird species composition, and the tree enrichment had a positive effect on bird and invertebrate communities. Insect biodiversity monitoring also has been conducted in 2018 and 2019 which indicated that enriched oil palm plantations using native tree species could enhance parasitoid and ants species richness. Tree enrichment had a positive impact on bird and invertebrate communities, however little is known about the effect of enrichment experiments on the ecological function provided by birds and insects. This study aimed to assess the effect of native tree enrichment on bird and insect parasitoid diversity in oil palm plantations, and also the plant-herbivore-carnivore interaction in the EFForTS-BEE research plot.

Bird surveys were conducted in the 20 x 20 m^2 (13 plots) and 40 x 40 m^2 (12 plots) sizes. Point counts with a radius of 50 m were used to bird survey from 6.00 to 10.00 am and, when necessary from 15.30 to 17.30 pm. Birds detected outside the radius of point count were also recorded but are not included in the calculation of bird diversity. Insect samplings were conducted using direct observation and traps. Lepidopteran larvae as herbivore representatives were collected and then observed daily. The lepidopteran larvae were observed daily to be recorded their development stages, parasitization rate, and the emerged parasitoid adult. A generalized linear mixed model has been used to analyze the parasitization rate Various plant diversity levels were set as a fixed factor and different plot sizes as a random factor in this experimental design.

A total of 33 bird species of 20 families were observed during the study, but only 24 species of 13 families were observed within the point count radius with total records of 345 birds (144 records in 20 x 20 m, and 201 records in 40 x 40 m). The most abundant species was Yellow-vented Bulbul (Pycnonotus goiavier). There were one protected species outside the radius of point count, i.e., the Changeable Hawk-eagle (Nisaetus cirrhatus).

Bird diversity was slightly higher in the larger enrichment plots (H' = 2.649; E = 0.845; Dmg = 4.418) than in smaller plots (H' = 2.291; E = 0.826; Dmg = 3.018). Based on its guilds, insectivores was the most dominant guild (48.5% of total species, 44.6% of total records), followed by frugivores (18.2% of total species, 28.5% of total records).

The study showed that larger plots of enrichment planting harbored higher species richness and diversity. As in other studies, oil palm plantation feeding guilds are dominated by insectivores. The bird species richness has increased in BEE plots by 57 % after 9 years of planting compared to the baseline data and one year after planting, suggesting that the enrichment plants had a positive impact on bird diversity in oil palm plantations. A similar result was found in the parasitization rate on herbivore insects, the parasitization rate was higher in the higher number of tree

enrichment diversity (Fig. 1). Plant species enrichment on oil palm plantation significantly affect the parasitization rate of parasitoid to herbivore (glmer: X^2= 8.58; p= 0.035). This finding strengthened previous results in the same experimental plot that parasitoid diversity increased in line with the increasing plant diversity enrichment. Biodiversity enrichment using the native tree in oil palm plantations may also increase the parasitoid-host interaction complexity (Fig. 2). Several frequent pest species that mostly reduced oil palm production, such as nettle caterpillar (Lepidoptera: Eribidae), slug caterpillar (Lepidoptera: Limacodidae), and bagworms (Lepidoptera: Psychidae) were found parasitized by parasitoid insect in the experimental plots. These results indicated the enrichment of the oil palm plantation gave benefits in providing ecosystem services, either provided by birds or insects.

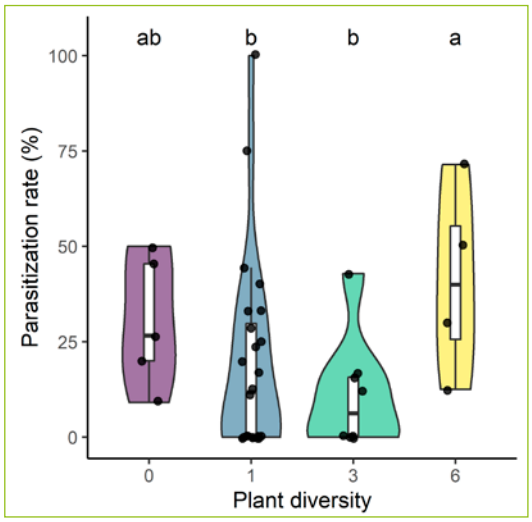
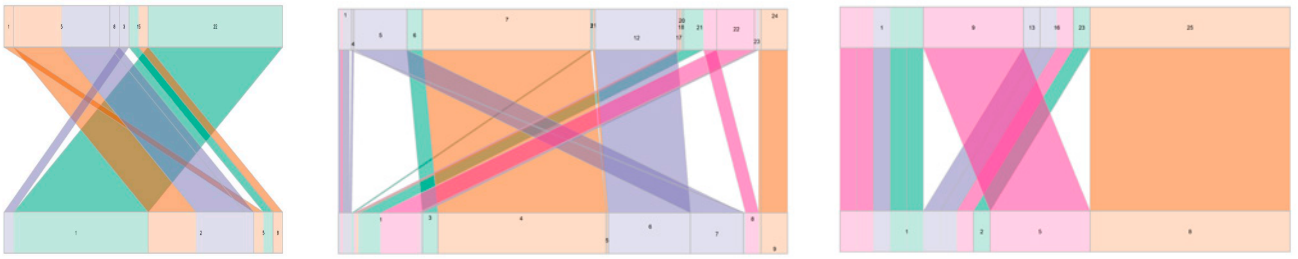


Figure 1. Parasitization rate in various plant diversity levels at Biodiversity Enrichment Experimental (BEE) plot at oil palm plantation. Different letters showed significant differences on Tukey HSD α = 0.05.



Different colors represent plot sizes: light green is 5x5 m^2, orange is 10x10 m^2, light blue is 20x20 m^2, and light magenta is 40x40 m^2. The upper columns indicate parasitoid species names and bottom columns indicate host species or family names.
Parasitoid: (1) *Triraphis* sp.01, (2) *Triraphis* sp.02, (3) *Triraphis* sp.05, (4) Triraphis sp.06, (5) *Trichogramma* sp.01, (6) *Carcelia falenarta*, (7) *Pediobius* sp01, (8) Hymenoptera sp01, (9) *Ceraphron* sp01, (10) *Trichogramma* sp02, (11) Chalcididae sp01, (12) Bethylidae sp03, (13) *Canaligoras* sp.01, (14) *Coccophagus gurneyi*, (15) Chalcidinae sp.01, (16) *Beyarslania* sp.01, (17) *Ceratosolen* sp.01, (18) *Apanteles* sp.01, (19) Exoristinae sp.02, (20) *Microplitis bomiensis*, (21) Bethylidae sp.01, (22) Eulophidae sp.01, (23) Hymenoptera sp.02, (24) Bethylidae sp.02, (25) Eulophidae sp.02.
Host: (1) *Erebidae* spp, (2) Limacodidae, (3) *Calliteara horsefieldii*, (4) *Mahasena corbetti*, (5) Noctuidae, (6) Crambidae, (7) Nymphalidae, (8) Geometridae, (9) Tortricidae, (10) *Calliteara* sp.

Figure 2. Interaction between parasitoid (upper column) and herbivore (bottom column) in various plants species diversity enrichments in oil palm plantation.