Community Contribution to Ecosystem Restoration in Giri Mulyo Village as a Role Model of Kerinci Seblat National Park, Jambi-Sumatra, Indonesia

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Abstract. Kerinci Seblat National Park (KSNP) experienced deforestation due to agriculture and plantation activities conducted by people residing around the national park. A role model concept was taken to address this problem, and to restore the forest by involving local communities in Giri Mulyo Village. The objective is to assess a model for ecological restoration and socio-economic support. Indicators include livelihood replacement, and tree species consisting endemic and multi-purpose (MPTS) biodiversity measured using biodiversity indices. Analysis of the species composition in the restored area shows Margalef species richness in the low category (0.88) but the Shannon diversity index ($H' = 1.72$) and Evenness ($E = 0.61$) suggest moderate diversity. The Simpson’s dominance index of 0.77 (away from 0) indicates that the site in Giri Mulyo Village is not dominated by a few tree species. These indices demonstrate biodiversity improvement compared to monoculture practices. This approach is a novel way to simultaneously resolve conflict and encroachment issues. Ideal scenario requires that MPTS commodities planted at a composition of at least 50% of the total tree density to support livelihoods. An alternative income source is still needed to compensate for the decreased agricultural income due to the restoration until MPTS can be harvested.

1. Introduction
Kerinci Seblat National Park (KSNP) was established in 1999 through the Ministry of Forestry and Plantation Decree No. 901/1999. This decree allocates 1,375,349,867 hectares (Ha) extending across Jambi, West Sumatra, Bengkulu, and South Sumatra provinces [1]. According to Government Regulation No. 28/2011, and Ministry of Forestry Regulation No. 76/2015, the national park is designated as a nature protection area (Kawasan Perlindungan Alam – KPA) to be managed through a zone system for research, science, education, supporting cultivation, tourism, and recreation. By this definition, KSNP is managed using a zone system that includes core, wilderness, rehabilitation, utilisation, traditional, and special zones [1] to achieve the functions mandated by the aforementioned regulations.
The main problem is deforestation due to agriculture activities in conservation areas. This is a pattern across Southeast Asia where the damage to ecosystems is predicted to cause 3% to 85% loss of biodiversity by the year 2100 [2]. The damages to the ecosystem due to deforestation threaten the existence of the Sumatran tiger (*Panthera tigris sumatrae*), an endangered species found in KSNP [3]. Main drivers of deforestation in KSNP include agriculture (horticulture) and plantation (mainly coffee) activities conducted by people residing around the park [4]. Zoning within the KSNP was reviewed in 2017 and 108,760 Ha of the park was designated as a Rehabilitation Zone [1] which is a deforested area subject to restoration activities. Approximately 6%, or 27,556 Ha, of the Rehabilitation Zone in the KSNP is located in Jambi Province [5].

The general concept for ecosystem restoration follows the Ministry of Environment and Forestry Regulation No. 105/2019 regarding implementation of land and forest rehabilitation. Based on this regulation, ecosystem restoration may employ one of three methods consisting of natural succession (natural re-growth); support for natural succession by enclosure (planting in area that already has trees to increase the tree density); and planting for total restoration [6]. Current approach in ecosystem restoration usually results in conflict between conservation area management with the local communities. The following challenges need to be addressed:

1. Improvement of ecosystem condition (reforestation) reflected in biodiversity indices; and
2. Eliminate tenurial conflict with local communities; and
3. Economic benefit for local communities in ecosystem restoration.

The legal framework to address these challenges is provided by the Directorate General of Conservation of Natural Forest and Ecosystem, Ministry of Environment and Forestry in form of Director General Regulation No. 6/2018 on conservation partnerships. This regulation covers conservation partnerships for ecosystem restoration and community development. Ecosystem restoration is expected to improve forest biodiversity based on vegetation structure, species (flora and fauna diversity), and ecosystem processes such as litterfall production and soil nutrients [7]. In addition, the focus of ecosystem restoration has also shifted in recent years, not only to increase the number and enrichment of species and habitat improvement, but also to be associated with environmental services provided by ecosystems [8]. Ecosystem restoration is an integrated approach involving disciplines of physiology, genetics, evolution [9], as well as social economic [10].

Addressing encroachment issues is also part of the objectives under bilateral cooperation programs. The Government of the Federal Republic of Germany is providing support to the Government of the Republic of Indonesia for integrated biodiversity and watershed management under a program known as Forest Programme II (FP II) and which runs from 2016 to 2022. FP II emphasizes on reforesting degraded areas and maintaining forest areas while improving livelihoods of the local communities. Specifically, the program consists of the following biodiversity, watershed, and social forestry components [12].

2. Objectives

The objective for the Role Model for ecosystem restoration in Kerinci Seblat National Park is to assess a model for ecological restoration combined with socio-economic support. Gradual restoration within the park is combined with potential income generation from commodities to offset the partial loss and decrease in productivity of horticulture land. Targets include tree density, livelihood replacement, and tree species biodiversity measured using biodiversity indices. Ultimately, ecological aspects of this Role Model Program are designed to achieve forest density of 250 trees per hectare within five years, or at least 500 trees/ha within ten years. These tree covers shall consist of 70% endemic tree species native to the park ecosystem, and 30% multi-purpose tree species (MPTS) to support livelihood and/or to offset the economic displacement caused by the Role Model Program. The composition of the endemic and the MPTS shall be arranged, as such to ensure high biodiversity (to be measured by biodiversity indices).

From a socio-economic perspective, the Role Model Program shall generate income from the harvest of MPTS commodities planted as part of the ecosystem restoration. Additionally, this program is expected to encourage community participation in restoring the ecosystem of KSNP; thus, reducing
tenurial conflicts between the park and surrounding communities, as well providing a novel approach in community conservation partnership scheme.

3. Methods
Role Model for ecosystem restoration in KSNP is aimed for ecological, as well as socio-economic purposes. The former sets for gradual reforestation of degraded (i.e., encroached) areas within the park, while the latter sets potential income generation from commodities to offset the displacement caused by the program (i.e., partial loss and decrease in productivity of horticulture land). Consequently, methods are designed to collect and analyze data for biodiversity, as well as economic indicators.

3.1. Study Area
The study area was defined as the restoration site (50.8 Ha) in Giri Mulyo Village, Kayu Aro Barat Sub-District, Kerinci District in Jambi Province, Sumatra Indonesia. Giri Mulyo Village, Kayu Aro Barat Sub-District, Kerinci District in Jambi Province is an example where extensive land conversion occurs. This village is located next to KSNP, and is bordered by government tea plantations and Gunung Labu and Kersik Tuo villages. The village is accessible by asphalt road from the district capital in Siulak which is 44 kilometers (Km) or 1.5 hours away by motor vehicle. Village infrastructure including village offices, community health centre, elementary schools, storage, and sport facilities are in good condition. A considerable portion of national park’s forest has been converted into potato and horticulture farms (dry-land farming) as the majority of people in Giri Mulyo Village are potato, chili, and cabbage farmers. A survey conducted by KSNP in 2018 revealed that 724.41 Ha of Park's area had been used for horticulture (mainly potato) by farmers for Giri Mulyo Village [11].

Restoration activities were completed by Karya Jaya and Danau Belibis community groups. The restoration area was an encroached area (currently used by the abovementioned community groups for horticulture/potato farming). The restoration area was located within an area designated as the Rehabilitation Zone of KSNP. Giri Mulyo Village is located in Cluster 1 (Kayu Aro Barat Sub-District) selected for FP II interventions, and within the jurisdiction of the Kerinci Utara Ranger Station. The vegetation cover of the restoration area is shown in figure 1 which indicates the contrast between the forested and the encroached areas in the upper and lower portions of the map respectively.

3.2. Study Period and Activities
The study was completed between November 2018 and December 2019. The Activities were designed to address the following variables:

1. Biodiversity: areas of restoration, numbers and types of seedlings produced and planted, and calculations of biodiversity indices; and
2. Economic: productivity of areas, economic displacement, and estimation time for economic offset.

3.2.1. Socio-economic survey
The socio-economic survey was conducted in Giri Mulyo Village using a Participatory Rural Appraisal (PRA) method that included focus group discussions (FGD) to obtain information on:

1. Village information (history of the village, natural resources within and outside national park area, identification of key figures and their respective roles, calendar of activities, and sketch of the village); and
2. Issues, and solutions to address village issues.
Figure 1. The existing condition of the target restoration area (shown with yellow arrows), as photographed using drone reconnaissance (source: Forest Programme II).

3.2.2. Preparation of map of restoration area
This consists of zonation review to ensure that the restoration area was within the Rehabilitation Zone of KSNP. This was done primarily by analysing the Park zoning map based on the Ministry of Forestry Decree No. 901/1999, and a park zoning review dated December 15, 2017 [13]. The zoning review was done by overlaying the cluster map (including village administration map) from FP II, park zoning map, and the encroachment map originating from drone surveillance.

3.2.3. Establishment of Seedling Nurseries
Seedling nurseries have been established to cultivate endemic species, and MPTS for planting activities in the park (initiated in December 2018). Two seedling nurseries 20 x 20 m (400m²) in size were established in Giri Mulyo Village. The nurseries were constructed from wood and steel frames with nets to provide adequate cover from direct sun and rain. The nurseries contained four to six rows of seedlings growing:

1. Endemic species consisting of Lauraceae and Podocarpaceae families collected from sprouts found around the root area of the main stem. A small amount of soil was collected with the sprouts in separate polybags from the original location and used for inoculation. These seedling polybags were placed in an area within the nursery with added plastic dome (sungkup) protection; and

2. MPTS seedlings include Avocado (Persea sp), Jackfruit (Artocarpus sp), and Cinnamon (Cinnamomum burmanii). These seedlings were originated from seeds, and were treated the same way as those of endemic species, but without the extra plastic dome (sungkup) protection.

3.2.4. Planting of Seedlings
Planting of the seedlings produced from the nurseries was completed at the beginning of the rain season in the second week of September 2019. The planting was designed with the following:

1. Seedling composition was 70% endemic species and 30% MPTS; and

2. Planting was done following 4 m x 10 m configuration per seedlings to allow existing potato / horticulture cultivations.
3.2.5. Biodiversity Analysis
Analysis of biodiversity was completed using four indices consisting of Margalef, Shannon-Wiener, Simpson’s, and Evenness index [14]. These indices were calculated based on the seedlings planted in the designated area.

3.2.6. Calculation of Economic Displacement
Economic displacement was calculated by deducting the areas for restoration from the total potato / horticulture farming area. Following the methods used for mounding in forest restoration [15], it was assumed that one tree requires a 4 m x 2 m clearing. Ultimately, economic displacement was reflected by the loss of productivity in a single event [16] calculated as:

\[ v(l) = \sum_{i=1}^{N} PR(L > l|Event_i) \cdot F_A(Event_i) \]

Where:
- \( v(l) \) is the exceedance rate of loss of productivity (income) reflected as IDR/year
- \( PR(L > l|Event_i) \) is the probability of occurrence (in this case = 1)
- \( F_A \) is the Frequency of occurrences (in this case = 1)
- \( Event_i \) in this case is the productivity of land parcel used for restoration \( Ha \) restoration x horticulture productivity x price per Kg (in IDR/year)

The economic valuation was done using business analysis, taking into account factors consisting of cost investment (seedling preparation, and planting), fixed cost (for maintenance), variable cost (fertilizers, herbicides, and transport), as well as revenue. The economic valuation was reflected as Unit-Output-Price [17] calculated as a natural logarithm of short-term profit considering input cost of fertilizers, seeds, labour, tools, and land area (in Ha).

Calculation of profit considered time (in years) required to harvest the restoration commodities (i.e., the MPTS). Additionally, economic valuation also identified Break-Even Point, marking a period where farmers started collecting the profits from their restoration commodities. Revenue under this calculation excluded planting and maintenance incentives from FP II. Such incentive will be accounted as other income. Economic valuation was done using conservative (pessimistic) and productive (optimistic) scenarios.

4. Results and Discussions

4.1. Ecological Perspectives of the Restoration
Karya Jaya and Danau Belibis farmer groups established two nurseries containing seven genera of endemic vegetation and three genera of multi-purpose tree species (Table 1). The composition of the planted tree species consists of 8,859 (70%) and 3,795 (30%) MPTS as planned for ecosystem restoration. Based on the tree genera, restoration done by community groups result in the compositions shown in figure 2. Medang Ringgit (Litsea spp) 24% and avocado (Persea sp) 38% are the highest endemic and MPTS tree species planted on site respectively.

The species richness (Margalef [DMg]), diversity (Shannon-Wiener [S]), as well as the species dominance (Evenness [E] and Simpson[D]) indices were calculated. The species richness index shows the total number of species in a community. Species richness index is required by sample size (and time needed to achieve it). The value of Margalef index is 0.88, while Shannon-Wiener index is 1.72. The diversity index measurement indicates the index value as moderate diversity on a scale of 1 to 3 [18]. The numbers of species used are small compared to the conditions of an undisturbed forest [19]. Species richness (\( H' \)) of tree species in Giri Mulyo site is at the low category (< 2.5), and this number can also be seen from the very small numbers of species used for restoration planting. This is lower diversity than measured in the surrounding natural forest area (\( H' = 2.89 \)) [20].
Table 1. List of species established in nurseries and planted by farmer groups.

| Local name          | Scientific name          | No. of Seedlings Planted by Farmer Group |
|---------------------|--------------------------|------------------------------------------|
|                     |                          | Karya Jaya | Danau Belibis |
| **Endemic**         |                          |            |               |
| Medang Ringgit      | *Litsea sp1*             | 2,261      | 848           |
| Pare-pare           | *Ligustrum sp*           | 657        | 1,927         |
| Medang Penjualit    | *Litsea sp2*             | 120        | 671           |
| Kayu Embun          | *Podocarpus imbricatus*  | 78         | 428           |
| Kayu Empening       | *Lithocarpus sundaicus*  | 120        | -             |
| Karamunting         | *Rhodomyrtus sp*         | 690        | -             |
| Kelat Putih         | *Ilex cymose*            | 52         | 523           |
| Balek Angin         | *Mallotus paniculatus*   | 52         | -             |
|                      | *Schima wallichii*       | 432        |               |
| **Total**           |                          | 4,030      | 4,829         |
| **MPTS**            |                          |            |               |
| Avocado             | *Persea sp*              | 761        | 690           |
| Cinnamon            | *Cinnamomum sp*          | 699        | 690           |
| Jackfruit           | *Arthocarpus heterophyllus* | 265      | 690           |
| **Total**           |                          | 1,725      | 2,070         |

Figure 2. Percentage endemic tree species and MPTS tree species.

The calculation of species dominance is 0.62 and 0.77 for the Evenness \([E]\) and Simpson’s indices respectively. These suggest that the composition of the tree species is not even (dominated by certain species). Calculation with Simpson’s dominance index shows that the dominance index value at 0.77. Simpson index shows that the dominance index is away from 0, according to [18] these results are expected based on the species planted in Giri Mulyo. The analysis of dominance supports the qualitative analysis showing *Litsea* spp and *Persea* spp as dominant species among endemic and MPTS groups respectively (Figure 2). A comparison of these four indices is shown in Figure 3. From the ecological perspective, moderate diversity is better than a low diversity expected from monoculture. The monoculture commodities are more susceptible to equalization [21]. These biodiversity indices can be used as indicators for species diversity in the future monitoring process.
4.2. Economic Perspectives of the Restoration

An economic survey in Giri Mulyo Village shows that majority (64%) of the population in this village work as farmers. The prime agriculture commodities consist of potato, chili, cabbage, and shallots. Additional plantation commodities in this village consist of sugarcane, coffee, and cinnamon. Areas used in this study consist of potato, chili, and shallot farm, so the economic analysis was completed based on these commodities. Areas managed by Karya Jaya and Danau Belibis groups are 23.02 and 27.56 Ha respectively. The annual income of both groups without restoration planting are summarised in table 2.

Ecosystem restoration uses a planting pattern that results in 250 trees/Ha. Using a 4 m x 2 m clearing for each tree, the reduction of productive area is calculated at 250 trees x 8 m$^2$, or 2,000 m$^2$ (0.2 hectares). This yields the formulation of a 20% displacement of currently productive farmland managed by the groups. Income from horticulture (business-as-usual and displaced scenario), and various commodities (avocado and cinnamon) per hectare are summarised in Figure 4 and Figure 5 respectively.

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These summaries are made based on a conservative scenario where one hectare of land is planted with only 75 MPTS trees, and a productive scenario where one hectare is planted with 140 MPTS trees. Additionally, the summaries are also made based on the assumption that price of these commodities remains constant throughout the years, and the price was calculated based on the lowest market price in September 2019. This analysis shows that the implementation of an ecosystem restoration program will cause two setbacks for the local farmer groups. These setbacks are the potential loss of income by 20% due to displacement (decreased land productivity/harvest), and additional costs required for planting the endemic and multi-purpose tree species.

Analysis for avocado and cinnamon commodities suggests that these setbacks will continue until the 11th year. In the 11th year, net income from multi-purpose tree species starts to match that of existing horticulture at approximately IDR 30 million/year/ha (displaced scenario) or IDR 37 million/year/ha (BAU scenario). A decrease in the existing harvest of horticulture is expected due to the increase of tree canopy from the planted endemic and MPTS species.

![Figure 3. Graph comparison Margalef Index, Shannon – Wiener Index, Dominance Simpson Index and Evenness.](image-url)
Table 2. Summary of group’s income per year without restoration planting (Business as Usual scenario).

| Group         | Number of members | Managed Area (ha) | Estimated production/harvest (kg) | Estimated income / harvest ('000 IDR) | Annual income assuming two harvests/year ('000 IDR) | Annual income/ha ('000 IDR) | Annual income/Ha/member ('000 IDR) |
|---------------|-------------------|-------------------|-----------------------------------|-------------------------------------|--------------------------------------------------|---------------------------|---------------------------------|
| Karya Jaya    | 34                | 23.02             | 105,300                           | 434,000                             | 868,000                                          | 37,706.34                 | 1,109.01                        |
| Danau Belibis | 38                | 27.56             | 107,900                           | 444,000                             | 888,000                                          | 32,220.61                 | 847.91                         |

Figure 4. Comparison of cumulative income from existing horticulture versus multi-purpose tree species (avocado) used in ecosystem restoration.

Figure 5. Comparison of cumulative income from existing horticulture versus multi-purpose tree species (cinnamon) used in ecosystem restoration.

5. Conclusions
To address the challenges this study provides the following conclusions:
1. Improvement of ecosystem condition (reforestation) is achieved, and is reflected as better biodiversity indices compared to monoculture (low indices); and
2. Local communities accepted the program and agreed to establish Conservation Partnership with Kerinci Seblat National Park Authority. This collaboration agreement is a novel way to resolve tenurial conflict and encroachment issues, where the conflicting parties reach an agreement to restore the damaged ecosystem in a win-win scenario between biodiversity-ecosystem function and sustainable agriculture; and
3. Economic benefit for local communities in ecosystem restoration is not yet observed during the study period, but the incentive for planting and plant maintenance provide additional income for local communities participating in ecosystem restoration.
It is recommended to increase the numbers of MPTS trees planted from 75 trees to 140 trees/Ha. Such increase in tree composition may provide potential income, and may be able to offset the displacement over time. Incentives for planting and maintenance, as well as additional support for alternative income need to be provided in order to further offset the displacement until the time when MPTS can be harvested. It is recommended that monitoring include ecological parameters such as tree density, the quality of the trees, and biodiversity indices, as well as economic parameters such as the income of the farmers.

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