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Population structure, vegetation composition and economic potentials of *Parkia timoriana* in Meru Betiri National Park, East Java, Indonesia

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Abstract. *Hidayati AN, Zuhud EAM, Andarwulan N. 2020. Population structure, vegetation composition and economic potentials of* Parkia timoriana *in Meru Betiri National Park, East Java, Indonesia. Biodiversitas 21: 203-210.* Kedawung (*Parkia timoriana* (DC.) Merr.) is one of rare medicinal plant species because it is only found in a small part of Indonesia. *P. timoriana* has high ecological and economic potential because it contains various active compounds such as anticancer. This study was aimed to investigate the population structure, vegetation community composition, and distribution, as well as the potential production and economic values of *P. timoriana* in rehabilitation zone in Meru Betiri National Park, East Java, Indonesia. The methods used were vegetation analysis, direct observation, and in-depth interviews with selected respondents using purposive sampling. We found that *P. timoriana* population at the study sites was only at tree and pole stages, while no sapling and seedling was found. This condition implies that regeneration of *P. timoriana* at the study sites was not happening which can threaten its sustainability in the future. *P. timoriana* dominated the vegetation at the studied sites which were indicated by the highest importance value index. Utilization of *P. timoriana* by the local community was by selling the seeds to medicinal industries or used as herbal medicine. While having conservation values, the management of *P. timoriana* stands in Andongrejo Resort also had the potential to generate economic values up to 17.6 billion rupiahs. Considering the great economic potential of *P. timoriana* and to ensure sustainability, so that nursery, breeding and regeneration of *P. timoriana* should be made in order to obtain the best quality seeds.

Keywords: Ethnobotany, rare medicinal plants, regeneration

INTRODUCTION

Indonesian flora plays an important role in world biodiversity as it contributes to 15.5% of total world flora (Sudarmono 2018). Indonesia has approximately 1,100 species of medicinal plants (Hargono 1985), more than 940 species of medicinal plants have been used for traditional medicine. Approximately 70% of the population of the developing country directly relies on traditional medicine for primary health care (Jaelani et al. 2018). Equally, the indigenous people of Indonesia have relied on medicinal plants for their health (Nugraha and Keller 2011).

Meru Betiri National Park was designated as a conservation area by the Minister of Forestry on May 23, 1997 with an area of 58,000 ha. Meru Betiri National Park is located in East Java Province in two regencies namely Jember Regency covering an area of 37,585 ha and Banyuwangi Regency covering an area of 20 415 ha (Zuhud 2007). Meru Betiri National Park has the zoning division of Meru Betiri National Park as follows: (i) core zone covering 28,707.7 ha, (ii) jungle zone covering 20,897.2 ha, (iii) marine protection zone covering 2,603 ha (iv) utilization zone covering 273.3 ha, (v) traditional zone of 285.3 ha, (vi) rehabilitation zone of 2,733.5 ha, (vii) special zone of 345 ha, and (viii) enclave of 2,155 ha (BTNMB 2011). Meru Betiri National Park is one of the national parks that has a rehabilitation zone covering an area of 2,733 ha based on the Decree of the Minister of Forestry of the Republic of Indonesia. KAIL, a non-governmental organization (NGO) stated that in 1998 there was massive deforestation within the Meru Betiri National Park area (before establishing the conservation area) on 4,000 hectares of teak land to be used as agricultural land. One cause was the management of the national park had not actively involved the community, as well as the access and economic contribution of Meru Betiri National Park was limited. Nowadays, within the deforested zone of 4,000 ha of former teak forest has been established as a rehabilitation zone based on the Decree of the Directorate General of Nature Protection and Conservation.

Previous study found that there were 239 species of medicinal plants (belong to 78 families) in Meru Betiri National Park. One type of medicinal plant grown in the rehabilitation zone is *Parkia timoriana* (DC.) Merr. which is locally known as kedawung (Zuhud 2007). *P. timoriana* is used by the community as a medicine to overcome stomach disorders such as bloating, cholera, inflammation of the intestine, intestinal worms, and chickenpox. The extract of *P. timoriana* seeds contains active compounds for anticancer in the form of alkaloids, flavonoids, phenolics, saponins and anthraquinones (Chanu et al. 2018). *P. timoriana* contains various active compounds that can be used to treat kidney disorders, diabetes, hypertension, headaches, leprosy, wounds, and diarrhea

(Angami et al. 2017). Furthermore, the powder produced from fruit pods mixed with water can be used as shampoo (Yusuf and Zuhud 2001). *P. timoriana* which has various active compounds can be used as alternative medicine in the future. However, the distribution of *P. timoriana* in Indonesia is very limited, which is only found in a small part of Sumatra, Kalimantan, Papua, and Java, while its population is increasingly rare (Sudiarto et al. 2002; ILDIS 2019). Therefore, conservation strategies are needed effort so that this species is not extinct in nature.

Despite *P. timoriana* is widely used by the community around Meru Betiri National Park as a medicinal plant (Zuhud 2007), yet regeneration aspects have not been a concern. The regeneration aspects are closely related to sustainability, therefore information is needed related to the condition of the *P. timoriana* population in Meru Betiri National Park. The results of Soejono (2014) provided information that the natural population of *P. timoriana* in Meru Betiri National Park was rare and in general, the *P. timoriana* tree stands were old. The results of the study were in line with the research of Zuhud (2007) which only found about 200 old stands in Meru Betiri National Park and some of them were no longer bear fruit. The same condition also happened in living collections in Bogor Botanic Gardens and Purwodadi Botanic Gardens. Presumably, the maximum age for *P. timoriana* to produce fruit is around 36 years since Soejono (1993) stated that *P. timoriana* living collection with 36 years of age in Purwodadi Botanical Garden can produce 13,000 to 15,000 seeds or equivalent to 8 to 10 kg of seeds.

In management practice by the community, *P. timoriana* is utilized by harvesting of kelp and fruit directly in nature. This method will threaten its sustainability because it does not provide the seeds to regenerate. Likewise, the use of *P. timoriana* sapling as a rootstock for its close relative, *Parkia speciosa* Hassk., results in a reduction in *P. timoriana* populations that live to adulthood (Rugayah 2014). This was the background of Wiriadinata and Bamroongrugsa (1994) suggesting *P. timoriana* as one of 30 species of rare Indonesian medicinal plants. Research on medicinal plants which has been done in general is related to the diversity of plants as raw material for medicines. However, research relating to the population, regeneration, and conservation of *P. timoriana* in nature has been limited. This study was aimed to investigate the population structure, vegetation community composition, and distribution, as well as the potential production and economic values of *P. timoriana* in rehabilitation zone in Meru Betiri National Park, East Java, Indonesia.

MATERIALS AND METHODS

Study area and period

The study was conducted in Meru Betiri National Park is located in Jember District, East Java Province, Indonesia. Meru Betiri National park is located between 8˚20'48 ''south latitude- 8˚33'48" south latitude and 113˚38'38 "east longitude- 113˚58'30" east longitude (Figure 1). The topography of the Meru Betiri National Park is generally hilly with a range of heights ranging from a height of up to 1,223 m above sea level, namely on the peak of Mount Betiri. Meru Betiri National Park area is a tropical rain forest with diverse forest formations which are divided into five types of vegetation, there are coastal forest vegetation, mangrove forest vegetation, swamp forest vegetation, rheophyte forest vegetation, vegetation located in rivers such as *Saccharum* sp. and lowland vegetation. This research is focused on the rehabilitation zone, Andongrejo Resort. The rehabilitation zone land management system at Andongrejo Resort uses an agroforestry system where farmers around the national park area manage land to be planted with agricultural crops and are obliged to maintain staple crops in the national park area (Figure 1). The study was conducted from August to September 2019.

Figure 1. Study area in Meru Betiri National Park is located in Jember District, East Java Province, Indonesia

Data collection

Data taken were in the form of ecological and socio-economic data. Ecological data included analysis of vegetation in each plot. The primary data collection method used a 20 m x 20 m nested plot using line plot sampling established on each block with a length of 100 m (Figure 2). The observation plot was selected using a purposive sampling method or a selection technique with certain criteria or considerations. In total, there were 60 observation plots within 12 blocks. Tools used in this study included Laser truPulse 360b technology, cameras, tape meters (1.5 m), roll measuring meters (50 m), and tally sheet.

Socio-economic data collected in this study were data related to the use of *P. timoriana* by local communities. In this case, the data was collected by conducting interviews with 30 local communities using purposive sampling method. Criteria for informants were farmers in the rehabilitation zone of the Andongrejo Resort who managed cash crops on the land.

Data analysis

Data were analyzed using quantitative and qualitative methods. Quantitative data analysis used various species diversity indexes. Vegetation data analysis using sample plots was carried out to see the composition of vegetation around *P. timoriana* by calculating the Importance Value Index (IVI) in the observation plots according to Cottam and Curtis (1956). The Importance Value Index for tree and pole levels was calculated as follows:

IVI = Relative Density + Relative Frequency + Relative Dominance

While, the Importance Value Index for sapling and seedling was calculated as:

IVI = Relative Density + Relative Frequency

Parkia timoriana habitat conditions were analyzed using species diversity index and evenness index on each observation block using several formulas, namely:

Species Diversity Index (H ')

Species diversity was analyzed using the Shannon-Wiener Diversity Index (Krebs 1989), with the formula:

$$H' = -\sum pi \ln pi$$

Where:
H ' : Diversity index
ni : Number of individuals
N : Total number of individuals

Evenness index (E)

Evenness Index (Index of Evennes) was used to determine the distribution of each species in each community. The Evenness Index formula was calculated as follows:

$$E = \frac{e^{H'}}{S}$$

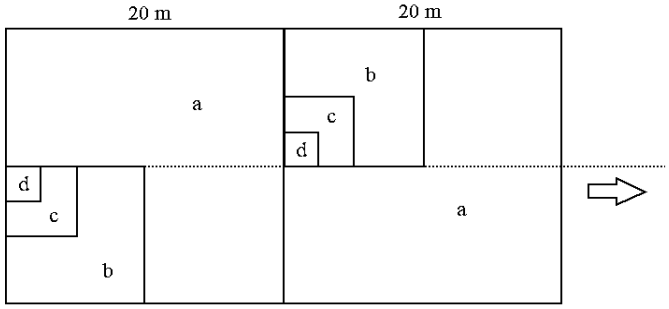
Where: H '= Shannon-Wiener diversity index, S = Number of species, E = Evenness index. Evenness index value ranges from 0-1, if the evenness index value is 0 then it indicates that the distribution of plant species in the community is very uneven (i.e. grouped or clustered), whereas if the value is close to 1 then all species are equally distributed/dispersed (Magurran 1988).

Data and information regarding the use of *P. timoriana* by community included the use of *P. timoriana*, process of harvesting and distribution of the harvested products which were analyzed descriptively by linked to the related literature as well as simple quantitative analysis.

Parkia timoriana seed production was estimated according to Rinekso (2000) and calculated as follows:

$$Y = 26.92\ X_1^{0.121}\ X_2^{1.03}$$

Where:
Y = number of fruit (board) production
X_1 = tree diameter (cm)
X_2 = header depth (m)



Note:
a : 20 m x 20 m
b : 10 m x 10 m
c : 5 m x 5 m
d : 2 m x 2 m

Figure 2. Plot design to collect data on *Parkia timoriana* vegetation at study site in Andongrejo Resort, Meru Betiri National Park, Indonesia

RESULTS AND DISCUSSION

Distribution of *Parkia timoriana* trees at Andongrejo Resort

In this study, the total number of *P. timoriana* trees recorded across 60 plots were 176 trees. The distribution of *P. timoriana* trees is mapped using GPS as presented in Figure 3. The results showed that the *P. timoriana* trees were dispersed fairly evenly across observation blocks. This is because *P. timoriana* was originally planted in 1999-2000 as the main species in the rehabilitation program in the rehabilitation zone of the Andongrejo Resort, Meru Betiri National Park. However, the presence of *P. timoriana* trees within the plot tended to be spread unevenly since it was planted according to agroforestry system so that other trees have also existed in the plot. The other rationale for the uneven distribution within the plots is different rates of mortality since some *P. timoriana* trees were found dead.

According to Krebs (1989), plants in their early stages of life have a high sensitivity to environmental conditions. Factors that limit the distribution of plants include climate, edaphic factors, and interactions with other plants. Therefore plant populations in nature generally spread in clusters and only slightly spread in other patterns. According to Ludwig and Reynolds (1988), factors that can influence the spatial patterns of living things, namely: (i) vectorial factors, namely factors produced by environmental actions (soil type, wind, light and water intensity), (ii) social factors, namely factors related to the behavior of organisms such as territorial, (iii) co-active factors, namely factors related to intraspecific interactions, and (d) stochastic factors, namely factors that result from random variations in some of the previous factors.

Population structure of *Parkia timoriana*

The population structure of *P. timoriana* in Andongrejo Resort is presented in Figure 4. The results showed that the population in the level of tree was the largest compared to other growth stages with 68 individuals/hectare followed by pole with 7 individuals/hectare, while there were no seedling and sapling recorded. This result suggests that that natural regeneration has not happened in the study area and if this condition continues without human intervention, the existence of *P. timoriana* in Andongrejo Resort will be extinct in the future. This is because *P. timoriana* has a maximum age in producing fruit to be 36 years of age (Soejono 1993).

The amount of density at each growth stage can be used to inform regeneration processes in natural habitat. Different in each growth stage, tree size and lifespan represents tree population dynamics, which may ultimately improve projections of forest dynamics under changing environmental conditions (Bigler 2016). According to Chen et al. (2014), the structure of plant populations always changes with time, one of the factors that cause changes in population structure is human activity such as land-use type, for example replanting to increase population or harvesting which can reduce population. *P. timoriana* in Andongrejo Resort area was used by the local community for its fruit. The harvesting activities by taking the whole fruits can hinder the regeneration of new individuals through seeds, resulted in no individual of seedlings and saplings.

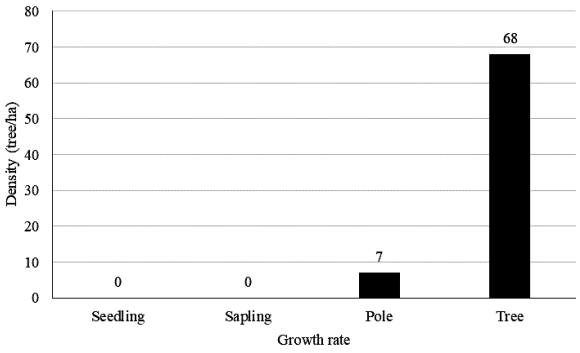


Figure 4. Population structure of *Parkia timoriana* in Andongrejo Resort across four growth stages

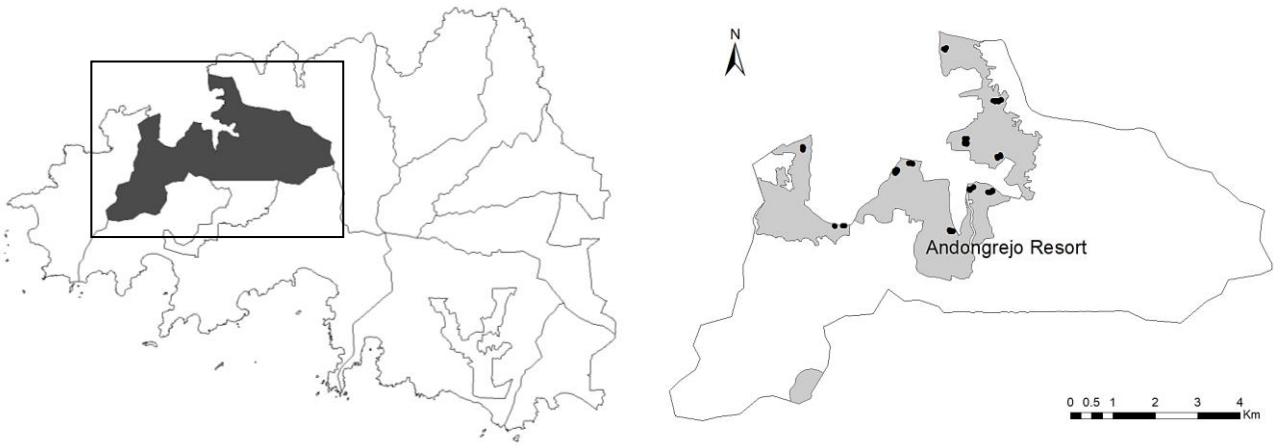


Figure 3. The distribution of *Parkia timoriana* in Andongrejo Resort, Meru Betiri National Park, Indonesia

Following Shankar (2001), the regeneration of *P. timoriana* can be categorized as follows: (i) good, if the number of seedlings is higher than the saplings and the number of saplings is more than the trees (seedlings> saplings> trees); (ii) fair, if the number of seedlings is higher than the saplings and the number of saplings is more or less the same as the tree (seedlings> sapling <tree); (iii) poor, if species are found only at sapling level, seedlings are not found (the number of saplings can be fewer, more, or equal to the number of trees); (iv) none, if the species found are only tree level and seedling and sapling species are not found; (v) new, if the species found are only seedlings and saplings and no tree-level species are found. The condition of *P. timoriana* population in Andongrejo Resort according to Shankar (2001) can be categorized as poor.

Natural regeneration in forest stands, including *P. timoriana*, can occur by seeds originated from the existing stands when seeds fall onto forest floor and develop into seedlings. On other words, distributions of *P. timoriana* represent the fundamental unit of biogeographical study, providing information about where *P. timoriana* is present and may interact with other species (Erhlen and Morris 2015).

Figure 5 shows that natural regeneration process of *P. timoriana* in Andongrejo Resort is not going well. Abnormal diameter class distribution patterns indicate failure of the regeneration process (Zuhud 2007). The highest distribution of diameter class was found in the growth stage of tree, while there were no saplings found. *P. timoriana* is a species of forest tree that morphologically has a large trunk with a crown and it is categorized as stratum A (top strata canopy) and is intolerant to sunlight (do not like shade). This is why natural regeneration in the forests is very difficult to occur (Zuhud 2007).

Vegetation analysis

The results of analysis of vegetation at the study site showed there were 15 species identified with *P. timoriana* dominated the vegetation with 176 species (Figure 6). This is not surprising because *P. timoriana* was the main species in the rehabilitation program in Meru Betiri National Park Office, so that the people who conducted the program have an obligation to protect them. Based on vegetation analysis, *P. timoriana* has the highest Importance Value Index (IVI) with 56.865 while the lowest was *Ceiba pentandra* (kapok) with IVI of 0.338. Furthermore, based on the results of observations in the field, there were no seedlings and saplings since the area was used for agroforestry land where agricultural commodity *Pueraria javanica* was planted. According to Saharjo and Cornelio (2011), the dominance of certain species in a community is when the species able to use most of the available resources compared to other species. The IVI values show variation in ecologically dominant from site to site. Hence, the IVI has helped in understanding the ecological significance of the species in the tropical dry deciduous forest (Narayan 2015). A plant species have the potential to become dominant if it grows in a suitable location to support its growth (Whitten et al. 1996).

Diversity and Evenness indices

Species diversity is an important index in community ecology (Mayer and Harms 2009). Meanwhile, Evenness index indicates the degree of distribution or dispersion of species. The diversity and evenness index in Andongrejo Resort are presented in Table 1.

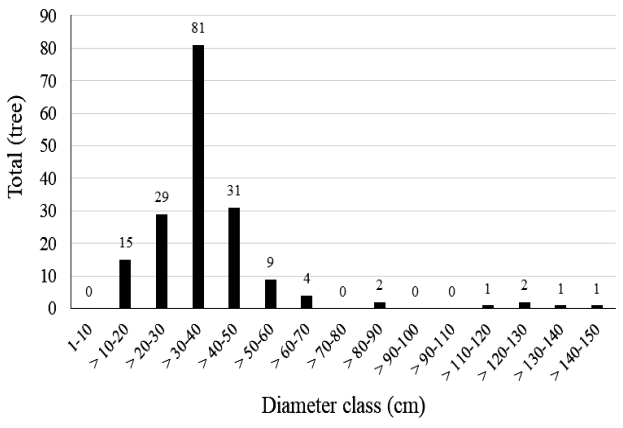


Figure 5. The diameter class of *Parkia timoriana* in Andongrejo Resort, Meru Betiri National Park, Indonesia

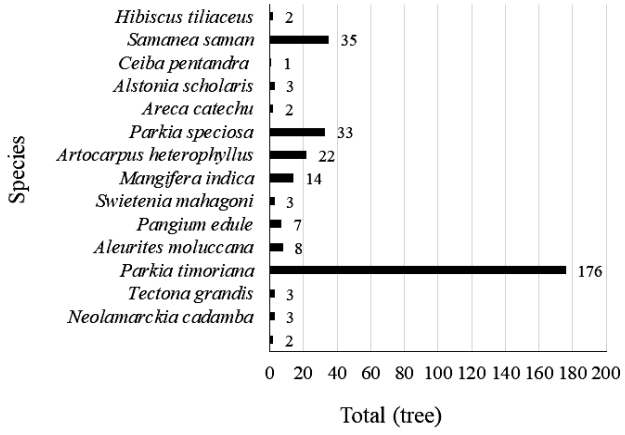


Figure 6. The composition of *Parkia timoriana* vegetation in Andongrejo Resort, Meru Betiri National Park, Indonesia

Table 1. The species diversity and evenness index for each block in Andongrejo Resort, Meru Betiri National Park

Observation block	Diversity Index (H')	Evenness Index (E)
Banjaragung	0.614	0.886
Barat Gumuk	0.810	0.452
Latin	1.264	0.705
Dam	0.355	0.323
Gentengan	1.218	0.878
Kandang Montor	1.072	0.773
Mbah Rogo	0.759	0.547
Sengoro	1.045	0.952
Timur Sawah	0.914	0.659
Utara Sawah 1	1.437	0.893
Utara Sawah 2	2.201	0.955
Wonowiri	0	0

Based on Table 1, the highest diversity index was found in the block of Utara Sawah 2 with 2.201, while the lowest diversity index was found in the Wonowiri block with 0. The plant communities in Andongrejo Resort, Meru Betiri National Park had relatively even distribution, because in general, the index value was close to one. The block of Utara Sawah 2 has the highest evenness index value compared to the other blocks with 0.955, while the lowest evenness index value is in the Wonowiri block with 0. The evenness index value close to 1 represents that almost all species in a population have the same abundance and indicates that the plant community is more evenly distributed. If the evenness index of a population is close to zero, then the distribution is more uneven (Magguran 2004). The smaller the value of E or close to zero, the more uneven distribution of species in a community which might be dominated by certain species, and vice versa the greater the value of E or close to one, then the species in the community are evenly distributed (Daget 1976).

Characteristics of *Parkia timoriana* farmers

The data of this study were obtained through interviews of 30 respondents in which 80% were male and 20% were female with main occupation was farming or agricultural labor. The proportion of male respondents was greater than women because men dominated land management activities. *P. timoriana* farmers in this study had ages of 33-64 years in which according to Subri (2003), these ages can be grouped as the productive age category.

The sources of knowledge possessed by farmers in terms of the use of *P. timoriana* were mostly inherited from their parents from generation to generation which was started by 27 respondents. Therefore, 90% of knowledge sources come from hereditary and 10% of knowledge sources were from self-study. This indicates the transfer of traditional knowledge and culture in Andongrejo Resort community.

Utilization of *Parkia timoriana*

Parkia timoriana trees used by local communities were *P. timoriana* planted in the rehabilitation zone along with other staple crops, such as *Musa* sp., P*angium edule* Reinw., *Parkia speciosa* Hassk., *Mangifera indica* L., *Aleurites moluccana* (L.) Willd., and Zingiberaceae. In the rehabilitation zone, the farmers implemented agroforestry system with agricultural crops such as bananas, Javanese chili, empon-empon, and *Pueraria javanica.* Regulations for managing the rehabilitation zone were locally called *tetelan* which is an agreement between the local community and the management of Meru Betiri National Park. In this scheme, the ownership of *P. timoriana* trees was based on land managed by the local community where the *P. timoriana* grows. So it can be said, when the *P. timoriana* tree grew on land managed by a farmer, it means such *P. timoriana* tree was owned by such farmer which has the right to utilize the *P. timoriana* tree. The ownership of *P. timoriana* tree can be inherited simultaneously with inherited land (*tetelan*).

According to respondents, *P. timoriana* trees generally start to flowering at the age of 5 years since planting with flowering period starts in July and the fruits are ready to be harvested in August-September. Each *P. timoriana* tree can produce an average of about 5 kg of *P. timoriana* seeds. There were several techniques for harvesting the seeds of *P. timoriana* carried out by the farmers. If *P. timoriana* fruit is not too dense then the harvesting is done by picking up the fruit that falls from the tree directly. However, if the fruit is dense, harvesting is done by installing stakes to climb the *P. timoriana* tree. Often, harvesting activities are done with the help of a pole. *P. timoriana* fruits that have been harvested are dried to separate the seed coat from the skin of the fruit by beating it using bamboo sticks or hammers made of wood. Dried *P. timoriana* seeds are then sold to collectors at an average price of Rp. 20,000- Rp. 35,000/kg depending on the quality of the seeds.

The marketing of *P. timoriana* seeds can be through three types of channels, starting from *P. timoriana* farmers to the consumers as presented in Figure 7. The dominant channel for marketing of *P. timoriana* was the third channel, which is farmers sell *P. timoriana* to the village collectors, then village collectors sell *P. timoriana* that has been collected from farmers to major collectors in the capital city (Surabaya, East Java), then large collectors sell *P. timoriana* to the herbal medicine industry according to supply demand. It seemed that *P. timoriana* farmers were very dependent on collectors in the village because they rarely sold their seeds directly to consumers. As for the major collectors, they are usually located in Surabaya, which is the capital of East Java Province, to be used as raw materials for herbal medicine industries. Meanwhile, the use of *P. timoriana* directly by the community was by drying and then ground into powder so that it can be mixed with honey or other mixes such as ginger to treat colic and colds.

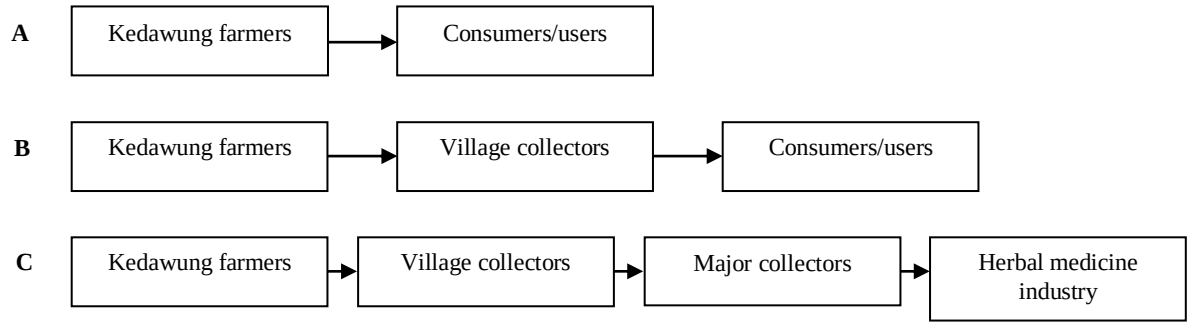


Figure 7. Marketing system of *Parkia timoriana* produced by farmers in Andongrejo Resort, Meru Betiri National Park, Indonesia

Economic potentials of *Parkia timoriana*

We estimated that the potential production of *P. timoriana* in Andongrejo Resort was 159,067 panicles/tree. If using the inventory results which found *P. timoriana* stands had density of 73.33 ind/ha and total rehabilitation zone in Andongrejo Resort was 1011.32 ha (TNMB 2016), it is estimated that the total production of *P. timoriana* per year around 11,796,774.02 panicles. If the average number of seeds per pod cluster is 12.7 seeds and the average weight of each pod of 12 grams (Zuhud 2007), then it can be calculated that the total potential production of *P. timoriana* seeds from Andongrejo Resort rehabilitation zone is 1,797,828.361 kg. Assuming that the average price of *P. timoriana* seeds is Rp. 25,000 per kg, then the potential economic value of *P. timoriana* in Andongrejo Resort is Rp. 44,945,709,020.648 (44.9 billion rupiahs) with the condition that all of the *P. timoriana* trees in Andongrejo Resort bear fruits.

Based on observations in the field, it was known that of the 176 trees recorded, there were only 69 trees (± 39.2%) that bear fruits. The fruiting trees had a diameter 40-141 cm. Taking into account the percentage of trees that bear fruit, the potential yield of *P. timoriana* seeds is 704,748.7174 kg with economic value of Rp. 17,618,717,936.0939 (17.6 billion rupiahs). Optimizing the economic potential of *P. timoriana* can be a major investment for local community welfare by facilitating greater allocations for communities involved in providing resources or allocating more funds for conservation and sustainable development. This is because the results of *P. timoriana* is herbal medicine through campaigns around the world for back to nature. Cultivation and regeneration of the existing *P. timoriana* in the national park area must be realized to avoid exploitation from the forest that causes the *P. timoriana* is rare. This effort was carried out to maintain the sustainability of the existing *P. timoriana* in the Meru Betiri National Park.

In conclusion, *P. timoriana* population in Andongrejo Resort is classified as unstable and natural regeneration was likely unsuccessful because there was no seedling and sapling that can be found despite a large number of trees and poles. Plant community in *P. timoriana* habitat had moderate diversity with a diversity index value of 1 <H ’<3 which was dominated by *P. timoriana*. *P. timoriana* stands in Andongrejo Resort were distributed evenly and were found almost in all rehabilitation zones. Utilization of *P. timoriana* by the community in Andongrejo village was by selling the seeds to medicinal industries or used as herbal medicine. Conservation efforts that have been carried out by the community around Andongrejo Resort were by harvesting the seeds of *P. timoriana* that were ready to harvest. While having conservation values, the management of *P. timoriana* stands in Andongrejo Resort had the potential to generate economic values up to 17.6 billion rupiahs. Considering the great economic potential of *P. timoriana* and to ensure sustainability, so that nursery, breeding, and regeneration of *P. timoriana* should be made in order to obtain the best quality seeds. Furthermore, given the existing stands of *P. timoriana* in rehabilitation zone of Meru Betiri National Park is too old it should be regenerated with the best plant seeds so that sustainability is guaranteed.

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