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What Can Native Trees Provide in Revegetating Tropical Degraded Land? An Experience of Man-Made Dipterocarp Forest in Indonesia †

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Abstract: The benefits of revegetation provided by the successful growth of planted vegetations. This paper described a successful initiative on the revegetation of tropical degraded land using native trees. More than 250 hectares of intact landscape in Gunung Dahu, West Java—Indonesia have been successfully revegetated using 32 Dipterocarp species. The success of this 20-years-old revegetated landscape was revealed by timber volume, natural regeneration, soil characteristics, ectomycorrhiza occurrence, and ecotourism potential. The results showed that the average diameter and height were varied from 12–43 cm and 10–23 m; diameter mean annual increment were at 0.6–2.1 cm year^{-1}; standing stock per hectares were at 10–220.84 m^3 ha^{-1}. The variations might be caused by different planted species, spacing distance, and planting technique. The natural regeneration success was observed by the offspring's occurrence from six *Shorea* species and supported by mycorrhiza fruiting bodies predominantly by the genus *Rusula*. Planted trees also improved the availability of organic materials to the soils, as described by the good total soil porosity (51.06–52.32%) and infiltration rate (120–15,533 mm hour^{-1}) at the site. The landscape also provided springs with continuous water supply and allowed tourists to experience the serenity of the tropical forest. Hence, revegetation using a native tree is prospective and proven to deliver a wider benefit in the ecological, economic, and social aspect.

Keywords: landscape restoration; indigenous tree; Shorea; standing stock

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1. Introduction

Land degradation and deforestation are among the major threats to both the environment and human-wellbeing due to the significant effect in losing biodiversity, causing soil degradation, and contributing to a significant greenhouse gas emission [1]. The rehabilitation of the degraded tropical forest has been an important issue in both the regional and global scale [2,3]. Planting of native indigenous trees for rehabilitating a degraded tropical forest is considered to provide multiple benefits such as timber, medical product, food, and ecosystem services [4–8].

Dipterocarps are major commercial trees of the tropics especially in the Southeast Asia rain forest [9,10]. The Dipterocarps family growing naturally in Indonesia spread throughout the islands of Sumatera, Kalimantan, Java, Sulawesi, Nusa Tenggara,

Moluccas, and Papua and consist of at least eight genera and 155 species [11]. The trees are ecologically important and significant commodities of tropical economies. Considering that many Indonesia dipterocarps populations are now in danger [12,13], a nationwide movement for conserving the species is needed [14–16]. Planting dipterocarps for forest rehabilitation and restoration has also been widely adopted in Indonesia [17,18] and several have been determined to provide faster growth such as *Shorea leprosula, S. parvivolia, S. johorensis,* and *S. platyclados* [19–21].

The Gunung Dahu Research Forest (GDRF) located at 06°36′30″–06°37′00″ and 106°34′00″–106°35′30″ was a revegetated area first established in 1997–1999 by planting Dipterocarp and originated both from shoot cutting and wildings. The aim of this paper is to review how the revegetation of degraded tropical land using dipterocarp trees can bring multiple long-term benefits as the revegetated landscape can provide timber stock, enrich soil characteristics, water and sanitation, ecosystem services, create a biological interdependent and natural regeneration capacity that resembles those in a natural forest.

2. Methodology

The first step in the development of this review was a search for peer-reviewed publications followed by a search for another web-based "grey" literature (guidebooks and conference proceedings). Local searches were carried out for a less visible publication specific to the targeted site of the revegetated Gunung Dahu landscape (unpublished data, village and other similar data records, institution reports, project reports, and modules). The lists of literature were then compiled and selected according to their relevancy on a specific section of the discussion. Other literatures on similar works were also added to our list. When available, open-publicly data were analyzed using similar tools as those stated in referred literatures to provide a similar value for comparison and discussion. Since the literature is relatively recent and specific on the site, a few examples from a similar project site within other tropical zones are included, in which these experiences might translate into a broader context for comparison and discussion.

3. Good Performance of Native Trees in the Man-Made Dipterocarps Forest Brings the New Insight

The measurement results for all planted dipterocarps showed that their average diameter at breast height ranged at 12–43 cm, the average height at 10–23 m, and the diameter mean annual increment (DMAI) at 0.6–2.1 cm year^{-1}. Based on their DMAI, the planted species might be categorized into four growth rates [22] including: Very fast (*S. platyclados, S. leprosula, S. ovalis, S. smithiana*), fast (i.e., *S. platyclados, S. leprosula, S. balangeran, H. gregaria, Anisoptera sp*), normal (i.e., *S. leprosula, S. selanica, S. pinanga, S. palembanica, S. macrophylla, S. stenoptera, S. guisso, H. bancana, V. sumatrana, H. dryonbalanoides, S. johorensis, S ribrera, D aromatica, D. oblongifolia, D. lanceolata, S. laevis*), and moderately slow (i.e., *S. mecisopterix, S. multiflora, S. curtisii, P. lucida, P. aptera, S. falcifera, S. seminis, A. marginata*). The highest DMAI value was shown by *S. platyclados* (2.1 cm year^{-1}). The same species may come to a different category of the DMAI rate depending on the planting distance and silvicultural treatment [23]. A more spacious planting distance allowed a higher DMAI value.

The calculations of the volume standing stock ranged at 10–220.84 m^3 ha^{-1}. The highest volume was reached for *S. platyclados* at a 4 × 8 m planting distance. On the other hand, *S. leprosula* with a 3 × 3 m planting distance also had a relatively high volume per hectare (215.412 m^3 ha^{-1}). The increased planting distance would yield a higher DBH and height growth but result in a lower volume per hectare due to the lower number of trees per hectare [12]. In accordance with the result of *S. leprosula*, the higher number of individual trees resulted in a high value of volume per ha. That result will support the effort of the stocking carbon where more individual tress will be preferred. The volume standing stock for many species in the revegetated study area was relatively high

compared to the standing stock potency in the logged over area/LOA (35 to 40 m^3 ha^{-1}) in Indonesia [24].

That result proved that dipterocarps in the man-made dipterocarps forest have better performance as they could reach the same value in a younger age. Hence, the good performance of dipterocarps species became an indicator that it could grow well outside its natural habitat and is very prospective to be planted as a restoration commodity in study areas, as well as other areas with almost similar conditions.

4. Natural Regeneration Capacity as a Key Indicator of Self-Sustaining Native Forest: Case Study from Prospective Species of *Shorea leprosula, S. pinanga,* and *S. platyclados*

Forest sustainability is closely related to the potential for natural regeneration in forests. Observations and measurements on the regeneration of this plantation forest were made on three model species, i.e., *S. leprosula*, *S. pinanga,* and *S. platyclados* in 2018 [25,26] and monitored again earlier in 2020 using the same method. The three red meranti from this revegetated site started flowering at 16 years for *S. leprosula* and *S. pinanga*, and 15 years for *S. platyclados*. Therefore, the age of the first flowering for these red meranti is in between the common plantation and natural forest. *S. platyclados* showed the most abundant natural regeneration (>23.000 seedlings) than *S. leprosula* (>11.000 seedlings) and *S. pinanga* (>450 seedlings). An observation made on an offspring's density showed that the number of seedlings was higher than those of saplings.

Compared to three other model species, the three Shorea, namely *S. selanica*, *S. macrophylla,* and *S. stenoptera* showed a less reproductive capacity as seen by the absence of survived seedlings for *S. macrophylla* and *S. stenoptera* and only five seedlings were found for *S. selanica*. Considering the age at first flowering, these three Shorea species also flowered at an older age compared to the other species. However, their reproductive ability could be determined as successful since many other species in the area have not yet shown their reproductive ability.

It can be concluded that during 20 years of revegetation, six species planted in the landscape have the capacity to develop natural regenerations on a different scale. *S. platyclados* showed the best natural regeneration with two flowering patterns which are rarely found in nature, i.e., annual and irregular flowering with a high number of survived offsprings. *S. pinanga*, *S. leprosula*, *S. selanica*, *S. macrophylla,* and *S. stenoptera* showed a less capacity of natural regeneration. It is recommended that artificial interventions are required for the seedlings survival and establishment in order to enhance the natural regeneration capacity.

5. Soil Characteristics, Land Productivity, and Potential Hydrological Value

Slopes also affect tree growth. Different slope gradients are known to have different impacts on the stand performance [23]. A gentle sloping class provides better growth for both the diameter and tree height. A gentle-sloping area has a thicker litter (11.7 cm) than the other slope classes (6.3–7.9 cm), while the litter thickness is thought to be the main factor in producing a greater diameter growth and tree height.

The function of the litter is essential, it will increase the nutrient content in the soil through the process of mineralization into an organic material, which is assisted by soil organisms, including soil fauna and flora. Chotimah et al. [27] reported that soil fauna under the *S. leprosula* stands in a revegetated landscape is dominated by ants and worms. Various ant species were found in the revegetated forest including Odontomachus denticulata, Anoplolepis gracilipes, Monomorium pharaonis, and Pheidole dentata. Meanwhile, earth worms found under the *S. leprosula* stands were Lumbricus terrestris and were found in almost all planting distances. The litter is considered to be the best food source for earthworms due to its relatively high carbohydrate content and low lignocellulose content.

The soil solum depth is also a major determinant in determining land productivity. The soil solum at the revegetated area was categorized as deep (>100 cm) as well as an effective root depth of around 90 cm that allows the plants to grow well. The impact of more than 20 years of revegetation activities in Gunung Dahu can also be measured in the context of improvement on soil physical properties. The nutrient cycle has been established in a revegetated site through the fallen litter of planted dipterocarp trees and converted into the available nutrients and minerals by the help of soil microorganisms.

Saputra [28] conducted observations of soil physical properties and found that the bulk density value was considered under high criterion and characterized by a high clay content that has high cohesiveness, enabling the increase in soil density [29]. The value of the total pore space belongs to a "good" criterion (51.06–52.32%), thus directly affecting the infiltration rate, which was categorized [30] as rather fast at the *S. leprosula* stand (120 mm hr^{-1}) and fast at the *S. selanica* stand (155.33 mm hr^{-1}). The higher infiltration rate at the *S. selanica* stand was strongly influenced by soil physical properties, namely high porosity and the presence of soil cover from understorey plants and litter. The correlation matrix showed that the infiltration rate in *S. selanica* stands positively correlated (0.643) with the value of the slow drainage pores.

6. Ectomycorrhizal Fungal Association Marks of How Man-Made Dipterocarp Forest has Grown to Resemble Its Natural One

Revegetation activities using dipterocarps trees carried out 20 years ago have changed the landscape of the Gunung Dahu Forest. At the time of planting, there were no ectomycorrhizas inoculated to the seedlings. However, the planted seedlings have grown and developed into forest stands and revegetation activities have transformed the degraded landscape into a lush and productive man-made dipterocarp forest.

After more than two decades of revegetation effort, research has been conducted to several experimental plots in this revegetated site and identified the occurrence of the ectomycirrhiza (ECM) family including Amanitaceae, Boletaceae, Hydnangiaceae, Russulaceae, and Schelodermataceae. The diversity index of ectomycorrhizal fungi in all the planting plots was medium, while the richness index and evenness index of ectomycorrhizal fungi were low. The ECM fruiting bodies showed a random distribution pattern and distributed evenly, with the most common species being the genera Russula and Boletus. A similar microclimate and soil characteristic may be the causing factor for the similarity of ECM found at each observation plot. The abiotic factor which was slightly varied was the different light intensity values between *S. leprosula* and *S. selanica* stands, while the composition of ECM fungi in *S. selanica* was higher (103 individu ha^{-1}) than in *S. leprosula* (69 individu ha^{-1}) stands [27,31].

Not to our surprise, in the unplanted land adjacent to those planted by the dipterocarp species, the ECM individual was not found [27]. From this condition, it is clear that the presence of ecto-mycorrhizae is highly correlated with the formation of the man-made dipterocarp forest, which was established as a result of the revegetation success of more than 20 years ago. The success of the restoration vegetation was followed by the development of the edaphic ectomycorrhizal community at the site.

7. Revegetated Landscape Deliver Environmental Services Value and Support Community Livelihood

The Gunung Dahu man-made dipterocarp forest has been transformed from almost a bare land area with few old pine trees into a densely planted forest landscape. This 20-years-old revegetated area has brought many benefits in the form of socio economic and also environment services. Aboveground tree biomass carbon stocks have been calculated and were varied depending on the silvicultural technique applied. The *S. leprosula* stand at a spacing distance of 2 × 2 m, 3 × 3 m, and 4 × 4 m has aboveground carbon stocks of 73.4, 85.6, and 45.4 tonnes C ha^{-1}, respectively, while the potential carbon stock of *S.*

selanica species at a spacing of 2 × 2 m, 3 × 3 m, and 4 × 4 m, respectively, are 66.9, 49.4, and 30.9 tonnes C ha^{-1} [32].

In addition to increasing the carbon stock, the revegetation activities changed the landscape characteristics. Therefore, it is no wonder that this man-made forest has been established as a popular spot for ecotourism. Based on the actual visitor record [33], the visit intensity is divided into three phases: Booming (June 2017–December 2018), steady (January 2019–March 2020), and pandemic or closure period (April 2020–present). In two active phases of booming and steady, the peak for the visit happens during the weekend with the average number of visitors 250–300 and 40–70 persons day^{-1}, respectively, while the weekday visits for both periods were 30–50 and 15–30 persons day^{-1}. The COVID−19 breakout also gave a significant impact on this aspect as the site was closed for public visiting since April 2020. The number of visitors coming to enjoy the scenery have created a multiplier effect for the surrounding community by generating new income from selling food, goods, and services, which in turn supported the community livelihood. More than 30 food counters opened at the site during the booming period that generated income for the seller of about IDR 600.000 (equal to around USD 42) and IDR 300.000 (equal to around USD 21) day^{-1} during the weekend and weekdays.

Five springs have been identified inside the forest, namely Cikutu, Gunung Menteng, Cilame, Pondok, and Legok Gintung springs [34]. The existence of the revegetation program to the established man-made forest received a positive assessment from the community surrounding the forest. To their perception, the successful revegetation activities gave a positive implication that the forested landscape delivered an important role in water management by providing a more continuous water supply and greater discharge from the existing springs than that before the revegetation took place.

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References

1. Yirdaw, E.; Tigabu, M.; Monge, A. Rehabilitation of Degraded Dryland Ecosystems—Review. *Silva Fenn* **2017**, *50*, 32, doi:10.14214/sf.1673.
2. Lamb, D.; Erskine, P.D.; Parrotta, J.A. Restoration of Degraded Tropical Forest Landscapes. *Science* **2005**, *5754*, 1628–1632, doi:10.1126/science.1111773.
3. Fisher, R.F. Amelioration of Degraded Rain Forest Soils by Plantations of Native Trees. *Soil Sci. Soc. Am. J.* **2006**, *59* 544–549, doi:10.2136/sssaj2005.0060er.
4. Castro, J.; Zamora, R.; Hódar, J.A.; Gómez, J.M. Use of Shrubs as Nurse Plants: A New Technique for Reforestation in Mediterranean Mountains. *Restor. Ecol.* **2002**, *10* 297–305, doi:10.1046/j.1526-100X.2002.01022.x.
5. Elliott, S.; Navakitbumrung, P.; Kuarak, C.; Zangkum, S.; Anusarnsunthorn, V.; Blakesley, D. Selecting Framework Tree Species for Restoring Seasonally Dry Tropical Forests in Northern Thailand Based on Field Performance. *For. Ecol. Manag.* **2003**, *184*, 177–191, doi:10.1016/S0378-1127(03)00211-1.
6. Kitao, M.; Yoneda, R.; Tobita, H.; Matsumoto, Y.; Maruyama, Y.; Arifin, A.; Azani, A.M.; Muhamad, M.N. Susceptibility to Photoinhibition in Seedlings of Six Tropical Fruit Tree Species Native to Malaysia Following Transplantation to a Degraded Land. *Trees Struct. Funct.* **2006**, *20*, 601–610, doi:10.1007/s00468-006-0075-1.
7. Kenzo, T.; Yoneda, R.; Matsumoto, Y.; Azani, M.A.; Majid, N.M. Leaf Photosynthetic and Growth Responses on Four Tropical Tree Species to Different Light Conditions in Degraded Tropical Secondary Forest, Peninsular Malaysia. *Jpn. Agric. Res. Q.* **2008**, *42*, 299–306, doi:10.6090/jarq.42.299.
8. Lamb, D. *Regreening the Bare Hills*; Springer, Business Media: New York, NY, USA, 2011.
9. Ashton, P.; Kettle, C.J. Dipterocarp Biology as a Window to the Understanding of Tropical Forest Structure: Where Are We Looking Now? *Biotropica* **2012**, *44*, 575–576, doi:10.1111/j.1744-7429.2012.00913.x.

10. Hiroshi, A.; Nakai, Y.; Hasegawa, G.P. Economic Importance of the Endemic Sumatran Lowland Dipterocarp Tree Species (Shorea Javanica). *Afr. J. Trop. Agric.* **2015**, *3*, 163–172.
11. Symington, C.F. *Malayan Forest Records No. 16, Foresters' Manual of Dipterocarps*; Universiti Malaya: Kuala Lumpur, Malysia, 1974.
12. Subiakto, A.; Rachmat, H.H.; Sakai, C. Choosing Native Tree Species for Establishing Man-Made Forest: A New Perspective for Sustainable Forest Management in Changing World. *Biodiversitas* **2016**, *17*, 620–625, doi:10.13057/biodiv/d170233.
13. Rachmat, H.H.; Subiakto, A. Conserving the Previously Reported Extinct Tree Species Dipterocarpus Cinereus: An Ex-Situ Approach for Species Conservation Strategy. In *Prosiding Seminar Nasional Masyarakat Biodiversitas Indonesia,Yogyakarta, Indonesia, March 31st, 2015*; pp. 560–564, doi:10.13057/psnmbi/m010331.
14. Rachmat, H.H.; Subiakto, A.; Susilowati, A. Mass Vegetative Propagation of Rare and Endangered Tree Species of Indonesia by Shoot Cuttings by KOFFCO Method and Effect of Container Type on Nursery Storage of Rooted Cuttings. *Biodiversitas* **2018**, *19* 2353–2358, doi:10.13057/biodiv/d190645.
15. Rachmat, H.H.; Fambayun, R.A.; Yulita, K.S.; Susilowati, A. Ex-Situ Conservation and Management of Dipterocarps Genetic Resources through Seedlings Collections and Nursery Establishment. *Biodiversitas* **2020**, *21* 556–563, doi:10.13057/biodiv/d210217.
16. Subiakto, A.; Rachmat, H.H. Exploration, Collection, and Conservation of Dipterocarps in Riau Islands. In *Prosiding Seminar Nasional Masyarakat Biodiversitas Indonesia, Yogyakarta, Indonesia, March 31st, 2015*; pp. 428–433, doi:10.13057/psnmbi/m010308.
17. Daisuke, H.; Tanaka, K.; Joseph Jawa, K.; Ikuo, N.; Katsutoshi, S. Rehabilitation of Degraded Tropical Rainforest Using Dipterocarp Trees in Sarawak, Malaysia. *Int. J. For. Res.* **2013**, *2013*, 1–11, doi:10.1155/2013/683017.
18. Kettle, C.J. Ecological Considerations for Using Dipterocarps for Restoration of Lowland Rainforest in Southeast Asia. *Biodivers. Conserv.* **2010**, *19*, 1137–1151, doi:10.1007/s10531-009-9772-6.
19. Ådjers, G.; Hadengganan, S.; Kuusipalo, J.; Nuryanto, K.; Vesa, L. Enrichment Planting of Dipterocarps in Logged-over Secondary Forests: Effect of Width, Direction and Maintenance Method of Planting Line on Selected Shorea Species. *For. Ecol. Manag.* **1995**, *73*, 259–270, doi:10.1016/0378-1127(94)03488-I.
20. Shono, K.; Davies, S.J.; Chua, Y.K. Performance of 45 Native Tree Species on Degraded Lands in Singapore. *J. Trop. For. Sci.* **2007**, *19*, 25–34.
21. Hassan, A.; Wahab, R.; Alias, M.A.; Salim, R.M. Growth Performance of 9-Years-Old Selected 5 Indigenous Wood Species Planted on Degraded Forest Land. *Int. J. Agric. Res.* **2007**, *2*, 302–306, doi:10.3923/ijar.2007.302.306.
22. Mindawati, N.; Tiryana, T. Pertumbuhan Jenis Pohon Khaya Anthotheca Di Jawa Barat. *Bull. Penelit. Hutan* **2020**, *632*, 47–58.
23. Pamoengkas, P.; Rachmat, H.H.; Khalifa, N. The Growth of Shorea Leprosula at Various Planting Distances and Slopes in Gunung Dahu Research Forest, Bogor, Indonesia. *Biodiversitas* **2020**, *21*, 4396–4404, doi:10.13057/biodiv/d210959.
24. Van Gardingen, P.R.; McLeish, M.J.; Phillips, P.D.; Fadilah, D.; Tyrie, G.; Yasman, I. Financial and Ecological Analysis of Management Options for Logged-over Dipterocarp Forests in Indonesian Borneo. *For. Ecol. Manag.* **2003**, *183*, 1–29, doi:10.1016/S0378-1127(03)00097-5.
25. Maulidah, I.; Pamoengkas, P.; Rachmat, H.H. Natural Regeneration Potential of Shorea Pinanga Scheff and Shorea Platyclados Slooten Ex Endert. in Gunung Dahu Research Forest, Bogor-West Java. *IOP Conf. Ser. Earth Environ. Sci.* **2019**, *394*, 012063, doi:10.1088/1755-1315/394/1/012063.
26. Nurkhaeni, W. *Potensi Regenerasi Alami Shorea Leprosula Miq. Di Hutan Penelitian Gunung Dahu, Leuwiliang, Kabupaten Bogoritle*; Bogro Agricultural University: Bogor, Indonesia, 2019.
27. Chotimah, T.; Wasis, B.; Rachmat, H.H. Population of Macrofauna, Mesofauna, and Ectomycorrhizae's Fruit Body at Shorea Leprosula Stand at Gunung Dahu Forest Research. *J. Penelit. Hutan Dan Konserv. Alam* **2020**, *17* 79–98, doi:10.20886/jphka.2020.17.1.79-98.
28. Saputra, N.E. *Analisis Sifat Fisik Tanah Dan Laju Infiltrasi Pada Berbagai Penggunaan Lahan Di Hutan Penelitian Gunung Dahu*; Bogor Agricultural University: Bogor, Indonesia, 2020.
29. Hakim, H.; Nyakpa, Y.; Lubis, A.M.; Nugroho, S.G.; Saul, M.R.; Diha, M.A.; Hong, G.B.; Bailey, H.H. *Dasar-Dasar Ilmu Tanah*; Universitas Lampung: Lampung, Indonesia, 1986.
30. Kohnke, H. *Soil Physics*; McGraw-Hill Book Company: New York, NY, USA, 1968.
31. Nuraini, T. *Keanekaragaman Fungi Ektomikoriza Di Hutan Penelitian Meranti Gunung Dahu Leuwiliang Kabupaten Bogor*; Bogor Agicultural University: Bogor, Indonesia, 2017.
32. Rachmat, H.H.; Fambayun, R.A. Restorasi Bentang Alam Terdegradasi: Pembelajaran Dari Beberapa Kisah Pemulihan Lahan Dengan Pengembangan Teknik KOFFCO. In *Konservasi KEHATI Skala Demo Plot*; Sawitri, R., Ed.; IPB Press: Bogor, Indonesia, 2019; pp. 269–300.
33. LMDH. *Association of Forest Village Community*; Lembaga Masyarakat Desa Hutan: Bogor, Indonesia, 2020.
34. P3H. *Gunung Dahu Long-Term Management Plan;* Pusat Penelitian dan Pengembangan Hutan: Bogor, Indonesia, 2020.