BIODIVERSITAS
Volume 20, Number 6, June 2019
Pages: 1681-1687

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d200625

Population structure of *Cotylelobium melanoxylon* within vegetation community in Bona Lumban Forest, Central Tapanuli, North Sumatra, Indonesia

ARIDA SUSILOWATI[1,♥], HENTI HENDALASTUTI RACHMAT[2,♥♥], DENI ELFIATI[1], CUT RIZLANI KHOLIBRINA[3], YOSIE SYADZA KUSUMA[1], HOTMAN SIREGAR[1]

[1]Faculty of Forestry, Universitas Sumatera Utara. Jl. Tri Dharma Ujung No. 1, Kampus USU, Medan 20155, North Sumatera, Indonesia. Tel./fax.: + 62-61-8220605, ♥email: arida_iswanto@yahoo.co.id

[2]Forest Research, Development and Innovation Agency, Ministry of Environment and Forestry. Jl. Gunung Batu No. 5, Bogor 16118, West Java, Indonesia. Tel.: +62-251-8633234; 7520067. Fax. +62-251-8638111. ♥♥email: hendalastuti@yahoo.co.uk

[3]Aek Nauli Forest Research Agency, Ministry of Environment and Forestry. Jl. Raya Parapat Km 10,5, Simalungun 21174, North Sumatra, Indonesia

Manuscript received: 5 May 2019. Revision accepted: 23 May 2019.

Abstract. *Susilowati A, Rachmat HH, Elfiati D, Kholibrina CR, Kusuma YS, Siregar H. 2019. Population structure of* Cotylelobium melanoxylon *within vegetation community in Bona Lumban Forest, Central Tapanuli, North Sumatra, Indonesia. Biodiversitas 20: 1681-1687.* In many forests stand, *Cotylelobium melanoxylon* is hard to find in the wild at present day because its bark has been intensively harvested for traditional alcoholic drink and sold by kilogram in traditional market in North Sumatra and Riau. This activity has put the species into serious threats of their existence in their natural habitat. We conducted study to determine the population structure of the species at seedling to tree stage in Bona Lumban Forest, Central Tapanuli. We used purposive sampling by making line transect at forest area where *C. melanoxylon* naturally grow. There were four transects with each transect consisted of five plots in which nested plots were established to record data at four growth stages, resulting in 80 plots in total. The result showed that the Important Value Index (IVI) for *C. melanoxylon* were 66.33, 17.65, 11.82, 12.90; Diversity Index (H) were 2.9, 1.90,2.88, 2.53 and 12.90, Index of evenness (E) were 0.844, 0.534, 0.85, 0.935 and the Index of Richness (R) were 5.71, 7.13, 5.37, 3.67 for the stage tree, pole, sapling, and seedlings, respectively This result demonstrates that *C. melanoxylon* still grows naturally in Bona Lumban at all stages from tree to seedling. However, there might be a problem in its natural regeneration as there is big difference of its high IVI at tree stage compared to IVI value for its younger stages. The regeneration status of *C. melanoxylon* was also classified into fair. This might be generated from the condition that the existing mature trees remaining were no longer productive and healthy due to excessive harvesting for its bark.

Keywords: Endangered species, quantitative, raru, structure

INTRODUCTION

Cotylelobium is a genus belonging to the family Dipterocarpaceae. It has five species and is found in Sri Lanka (2 species), Peninsular Thailand (2 species), Peninsular Malaysia (2 species), Sumatra (1 species) and Borneo (3 species). The timber of *Cotylelobium* spp is traded in Indonesia under the name "giam", which may cause confusion because this is the trade name for the heavy wood of *Hopea forbesii* (Borstow 2018). In Bataknese ethnic, *Cotylelobium* is known as "raru". This species grows wildly in primary or secondary forest mixed with other stands. Of the five species in Cotylelobium Genus, only one species is found in Sumatra mainland and some small islands surrounding it (Rachmat et al. 2018) with the name *Cotylelobium melanoxylon.* Even though it has been believed that there is only one species in Sumatra region of *Cotylelobium*, recent finding suggests that other species, *C. lanceolatum,* may also occur in Bunguran Island of Natuna, Riau Islands (Subiakto and Rachmat 2015).

Cotylelobium melanoxylon is a medium-sized to large tree with cylindrical bole. Its timber has a high economic value and is classified as heavy wood which is good for many purposes (housing, railway, bridge, etc.). However, current field survey shows that the species is getting harder to find in the forest. Heavy exploitation targeted for its barks seems to be the most significant contribution for its population loss. This species is hardly seen in the wild at present day since local community harvests its bark to make traditional alcoholic drink (Subiakto et al. 2017). Bataknese ethnic utilize raru bark as important source for mixing material in traditional alcoholic drink called *tuak* (Pasaribu 2009) and is sold by kilogram in traditional market in North Sumatra. Local people also use the barks and leaves of raru for traditional medicine of diarrhea, malaria (Sorianegeara and Lemmens 1994) and diabetes (Matsuda et al. 2009).

In Sumatra mainland, *Cotylelobium melanoxylon* is recorded mostly from Riau and North Sumatra. In Riau, they are found in Bukit Tiga Puluh and Tesso Nilo National Parks, in North Sumatra, they are reported growing naturally in Barus while in small islands surrounding Sumatra they are known to grow naturally in Mursala Island (Subiakto et al. 2017, Rachmat et al. 2018). The concern upon extinction of this species has been sounded by Barstow (2019) and listed raru in IUCN red list as least concern status. Bona Lumban is one of raru production area in North Sumatra. In this area, the harvesting of raru's bark and wood is still conducted by local people. Forest conversion into palm oil plantation has also threatened the existence of this species and will affect floristic composition and population structure of the forest.

Quantitative analysis of population structure of the species is able to describe the number of individuals in each growth stage of species to determine its productivity which is characterized by adequate number of individuals in each growth stage in a forest community (Reddy et al. 2008). It also depends on the ecological characteristics of the sites, species diversity and regeneration status of a species (Mishra et al. 2013). Quantitative analysis of diversity and regeneration status of tree species is important because it may provide baseline information to formulate conservation and management strategies for the species. Saxena and Sight (1982) state that quantitative structure of forest characterized by the presence of sufficient population of seedlings, saplings and young trees indicate a successful regeneration of forest species, while adult trees may provide as source of seeds The presence of sufficient number of seedlings, saplings and young trees will determine the successful regeneration and is influenced by some biotic and abiotic factors.

Several disturbances like logging, landslides, gap formation, litterfall, herbivory, fire, grazing, light, canopy density, soil moisture, soil nutrients, and anthropogenic pressure can affect the potential regenerative status of species composing the forest stand spatially and temporally (Rao et al. 1990). Due to this consideration, our research was conducted to determine the population structure of *Cotylelobium melanoxylon* at seedling to tree stage at Bona Lumban Forest-Central Tapanuli, one of the important *raru* material sources in North Sumatra.

MATERIALS AND METHODS

Site location

Bona Lumban is known as one of *raru* bark producer in North Sumatra. According to local people's information, many kilograms of *raru* bark is sold to other districts for *tuak* mixture every day. Bona Lumban is a village located in Tukka Sub-district, Central Tapanuli District that covers an area of 6.80 km^2 (BPS 2016). Central Tapanuli District has the average temperature of 26.40^{0}C with the highest may reach up to 32.20^{0}C while its lowest temperature is around 22.40^{0}C. The average of relative humidity is 82.50% and rainfall at around 12 mm/year (BPS 2016). Jurisdictionally, in term of forestry regulation, the forest in Bona Lumban village is located in two types of land status which are Protection Forest (*Hutan Lindung/HL*) and Area for Non-forestry Uses (*Area Penggunaan Lain/APL*).

Vegetation analysis

Vegetation analysis was carried out using purposive sampling based on local people information on the occurrence of *C. melanoxylon* (Figure 2), in certain sites of the forest (Jumawan et al. 2015). Species identification was carried out by employing a botanist. Few species which were still doubtful were taken for their specimens to be confirmed later in the herbarium. There was total of four transects established at the studied sites where *C.melanoxylon* occur with five plots/quadrats for each transect.

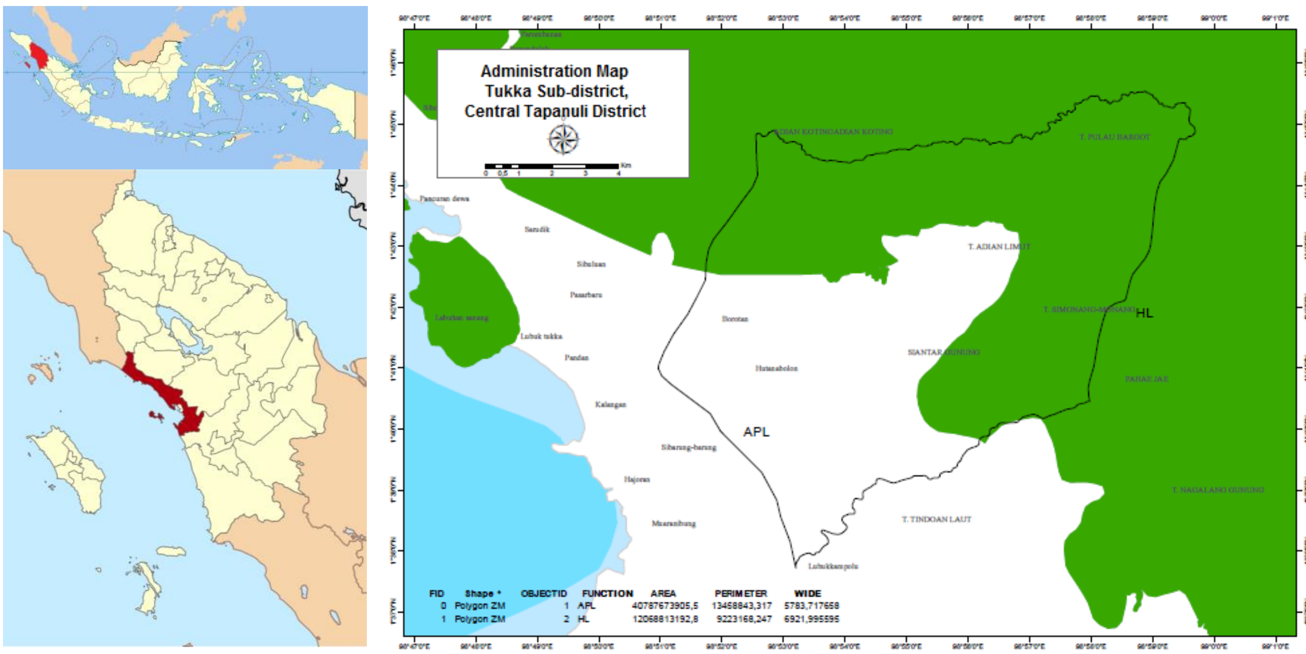

Figure 1. Research location in Tukka Sub-district, Central Tapanuli District, North Sumatra Province, Indonesia

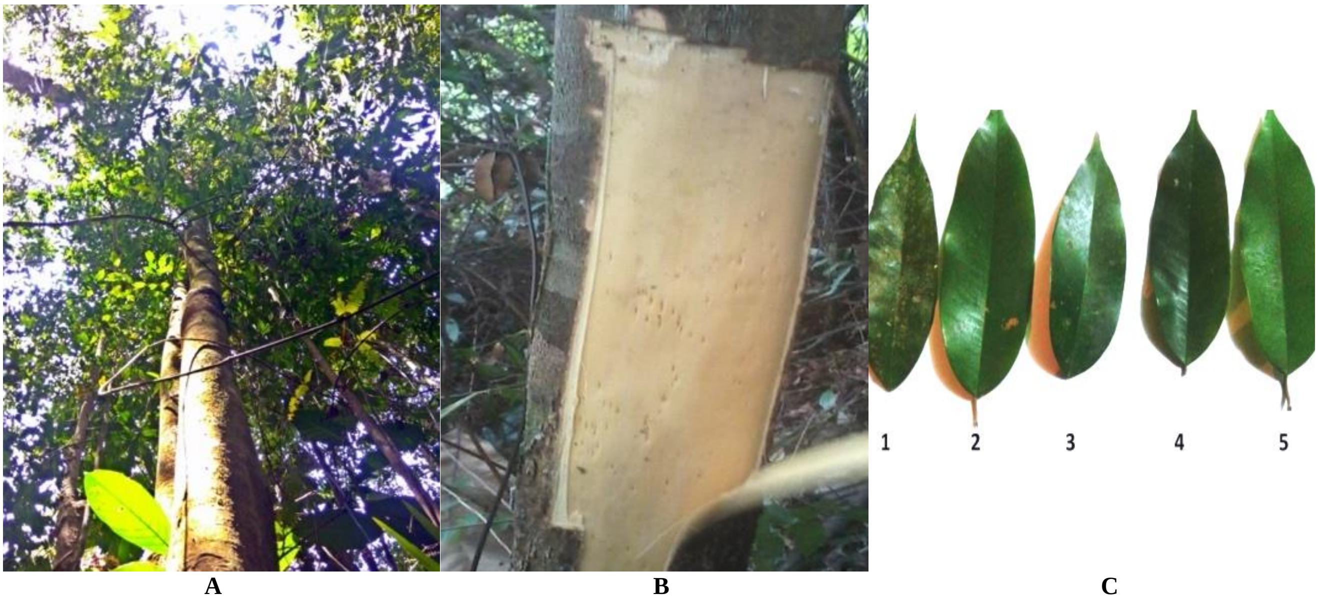

Figure 2. *Cotylelobium melanoxylon* in Bona Lumban Forest, Tukka Sub-district, Central Tapanuli District, North Sumatra Province, Indonesia. A.Stem and canopy part, b. Bark and wood, C. Leaf

A line was drawn for each transect starting from the forest edge with the minimum length of transect was 200 m. In each transect, nested plots were established with the size of 2 x 2m2, 5 x 5 m2, 10 x 10 m and 20 x 20 m2 to record all necessary data for seedling, sapling, pole, and tree, respectively. The observed variables for each stage are as follows: (i) Seedling stage (germinated seed to < 1.5 m in height): species, number of individual of each species, (ii) Sapling stage (height >1.5 m to diameter at breast height (dbh) < 10 cm): species, number of individual of each species, (iii) Pole stage (≥ 10 cm dbh < 20 cm): species,dbh, height, (iv) Tree stage (DBH>20 cm) : species, dbh, height

These data were used to calculate relative density, frequency, abundance, and dominance of the species; and from those values, the Importance Value Indices (IVI) were calculated.

Data analysis

To express the dominance and biological success of any species with a single value, the concept of Importance Value Index (IVI) have been developed by Curtis and McIntosh (1950), Phillips (1959) and Misra (1968). Rastogi (1999) and Sharma (2003) have reported the IVI as a better expression of the relative ecological importance of a species than an absolute measure such as frequency, density or dominance. IVI of each species was obtained by summing the three relative values, i.e., relative density (RD), relative frequency (RF) and relative dominance or relative basal area (RBA), in which IVI = RD + RF + RBA (1). Importance percentage was obtained by dividing the IVI value by 3.

Relative density

Density denotes the average number of individuals of a given species out of the total of samples examined in a study area (Oosting 1942; Rastogi 1999; Sharma 2003). The Relative Density (RD) was calculated using the formula:

$$RD= \frac{\text{Total number of individual of a species}}{\text{Total number of all individual of all species}} \text{X}100\%$$

Relative frequency

Frequency indicates the number of sampling plots in which a given species occurs as a percentage of all sampling plots and based on the presence or absence of a species (Raunkaier 1934; Rastogi 1999; Sharma 2003). Relative Frequency (RF) was calculated using the formula:

$$RF = \frac{\text{Frequency of a species}}{\text{Frequency of all species}} \times 100\%$$

Relative basal area

Dominance is defined as the sum of basal areas of all individuals of a species. The basal area refers to the ground covered by the stems (Rastogi 1999; Sharma 2003). Relative Basal Area (RBA) was calculated using the formula:

$$RBA = \frac{\text{Basal area of a species}}{\text{Total basal area of all species}} \times 100\%$$

Regeneration status

The regeneration status of tree species was determined based on the presence of seedlings, saplings and mature stage (Khumbongmayum et al. 2005). The regeneration status of species was classified into five categories. The categories were: (a) 'good', when seedlings > or < saplings > adults; (b) 'fair', when seedlings > or ≤ saplings ≤ adults; (c) 'poor', if a species survives only in sapling stage, but no seedlings (though saplings may be <, > or = adults); (d) 'none' or 'not regenerating' if it is absent both in sapling and seedlings stages, but is found only in adults and (e) 'new', if a species has no adults, but only saplings and/or seedlings.

Species diversity

The species diversity was determined by using Shannon-Wiener.

The index was formulated as: $H' = \sum pi \ln pi$;

Where, pi is the proportion of individuals of i^{th} species and individuals of all the species in a stand.

The concentration of dominance (cd) was determined by Simpson's index:

$cd = \Sigma (pi)^2$;

Where, pi is the same as for Shannon-Wiener Information Index.

The equitability or species per log cycle index was determined as E:

$E = S / (\log n_{i} - \log n_{s})$;

Where, S is the number of species in that stand, n_i and n_s are the density value of most and least important species, respectively

RESULTS AND DISCUSSION

Vegetation analysis

Plants and living components of forest system determines the structure and function of forest ecosystem (Richards 1996). The existence of forest ecosystem influences plant diversity, species distribution, and abundance pattern. The richness of plant species is controlled by variety of biotic and abiotic factors such as topography, soil, climate and geographical location (Ram et al. 2004). Each forest has a distinct floristic composition which varies in its species richness and the abundance of different species. Environmental variability in terms of climatic factors, social resources, grazing by herbivores and human interference are the critical factors which contribute in the spatial and temporal patterns of vegetation of an ecosystem (Chapin et al. 1993).

Based on the analysis of vegetation in Bona Lumban forest to all plant stages, it was recovered that there were 15-35 species found at each stage of the plant (data not shown). *C.melanoxylon* is always available at every plant stage, indicating its complete occurrence in Bona Lumban Forest. The result of vegetation analysis of *raru* at different growth level is described below.

Table 1. Important value index (IVI) of raru at seedlings stage in Bona Lumban forest area, North Sumatra, Indonesia

Species	Relative density	Relative frequency	IVI
Ficus consociata	17.02	17.39	34.41
Maduca curtissii	12.77	13.04	25.81
Gluta renghas	10.64	10.87	21.51
Shorea leprosula	8.51	8.70	17.21
Syzygium acuminatissimum	8.51	8.70	17.21
Cotylelobium melanoxylon	6.38	6.52	12.90

Seedling

There were 15 different species at seedling stage. *Ficus consociata* was found to be the species with the highest RD, RF, and IVI value followed by *Maduca curtissii* and *Gluta renghas* (Table 1). It indicates that at seedling level *F. consociata* denotes their range of niche preferences and capability to establish over a large area. Its highest IVI also depicts the phytosociological structure of *F. consociata* in the natural habitat, showing an overall picture of ecological importance of the species. This finding is also in accordance with Chaudary et al. (2012) who states that *Ficus* spp. are keystone species in tropical rain forests that play very fundamental role in ecosystem due to its abundance fruits throughout the year. It might be the cause of the abundance of *F. consiana* at seedling stage.

Cotylelobium melanoxylon ranked 6^{th} in term of RD, RF, and IVI, indicating that this species has been facing certain constraints. According to Ashton (1982), this condition might be as consequence from disrupted seed dispersal, the vulnerability of the seed from decaying or even because of the isolation process and soil characteristics changes. Furthermore, Lee et al. (2002) state that *C. melanoxylon* has specific microsite due to its preference for good drainage soil and good light intensity. The canopy closure of Bona Lumban forest also contributed in lower density of this species at seedling stage.

Sapling

Rather similar to those of seedling stage, the value of *C. melanoxylon* IVI at sapling stage (Table 2) was 11.82 and ranked 5^{th} among the five highest IVI value in the plots. At this stage, it was found that *Ficus consociata* and *Syzygium acuminatissimum* were excluded from the 5 highest IVI value and replaced by *Calophyllum soulattri*. It might be caused by environmental changes or human activities which reduce the population of this species at sapling level. Horisson et al. (2003) state that fig species have stringent microsite for seedling survival. Many fig species are vulnerable after root establishment. In contrary, *Shorea leprosula* was found to have the highest RD, RV and IVI value at sapling stage. According to Lee et al. (2002), *S. leprosula* needs partial shade for seedling establishment but its later growth responds greatly to light. The light condition at sapling stage was able to promote the occurrence of this species.

Table 2. Important value index (IVI) of raru at sapling stage in Bona Lumban forest area, North Sumatra, Indonesia

Species	Relative density	Relative frequency	IVI
Shorea leprosula	21.62	10.48	32.60
Gluta renghas	10.81	8.54	19.35
Maduca curtissii	9.46	8.54	18.00
Calophyllum soulattri	4.50	7.32	11.82
Cotylelobium melanoxylon	4.50	7.32	11.82

Table 3. Important value index (IVI) of raru at pole stage in Bona Lumban forest area, North Sumatra, Indonesia

Species	Relative density	Relative frequency	Relative basal area	IVI
Meranti (*Shorea* sp.)	7.63	7.96	8.13	23.72
Gluta renghas	7.63	7.08	7.45	22.15
Syzygium acuminatissimum	6.78	7.08	5.38	19.24
Cotylelobium melanoxylon	6.78	4.42	6.44	17.65
Maduca curtissii	5.08	5.31	5.75	16.15

Table 4. Important value index (IVI) of raru at tree stage in Bona Lumban forest area, North Sumatra, Indonesia

Species	Relative density	Relative frequency	Relative basal area	IVI
Cotylelobium melanoxylon	25.65	17.78	22.79	66.23
Bogor	7.85	8.89	7.92	24.66
Meranti (*Shorea* sp.)	8.38	4.44	9.12	21.94
Shorea forbesii	8.90	4.44	6.49	19.83
Dryobalanops aromatica	6.28	5.56	3.39	15.23

Pole

Pole stage is characterized by typical lowland tropical forest when dipterocarp species (meranti) start to take over the dominance of species occupancy in the site. Dipterocarp species are typically canopy trees or emergent and reach considerable dimensions throughout forests in the region. As those at seedling and sapling stages where *C. melanoxylon* ranked 6th and 5th, at the pole stage, *C. melanoxylon* ranked 4th (Table 3). Species with high IVI value at seedling, sapling and pole stage presume will also dominate the next stand structure. It is in accordance with Soerianegara and Indrawan (1982) who state that regeneration stage (seedlings, saplings, and poles level) will be as substitute tree for old or dead trees.

Tree

At the tree stage, the dominance of dipterocarp species was more apparent. Among the 5 highest IVI index, only species with local name of Bogor was determined as non-dipterocarp. All four other species were dipterocarps such as *C. melanoxylon* (ranked 1st), *Meranti* (ranked 3rd), *Meranti merah* and *Dryobalanops aromatica*. The same finding was also found by Ashton (1998), who stated that *C. melanoxylon* was the dominant tree at tree stage compared to other dipterocarp species.

Based on Tables 1, 2, 3 and 4 there is no consistent rank of species IVI at every growth stage. It indicates that the species have different ecological importance at each stage. Our research also found four threatened dipterocarp species based on IUCN listing; they were *Cotylelobium melanoxylon* as Endangered (Asthon, 1998), *Shorea leprosula* as Near Threatened (Pooma and Newman 2017), *Dryobalanops aromatica* as Vulnerable (Barstow and Randi 2018) and *Shorea forbesii* as Vulnerable (Pooma and Newman 2017).

Regeneration status of *C. melanoxylon*

Regeneration is the ability of a species to complete the life cycle and a key process for the existence of species in a community under varying environmental conditions (Khumbongmayum et al. 2005). Common studies of tropical tree regeneration only focus on seedlings stage, which is usually more abundant than mature stages (Tripathi and Khan 2007). According to Sukumar et al. (1992), regeneration of tree species is considered and classified based on the abundance of seedling and compared to mature stage condition. Based on data above, seedling and sapling density of *raru* was lower compared to the mature stages. It suggests that the regeneration status of *raru* in Bona Lumban forest was classified into fair.

Fair regeneration is defined as the condition in which there are a fair number of seedlings, but the percentage of saplings is either lower than or close to that of the mature trees (Woo et al. 2011). It indicates a problem in its natural regeneration. Tree seedling recruitment on *raru* is limited by either low/uncertain seed supply and establishment or lack of favorable microsites and factors that affect early seedling growth and survival. There is no information about the phenology and natural regeneration of this species in Indonesia, but according to Appanah and Turnbull (1998), this species has low natural regeneration. It might be caused by seedlings that die primarily from the very low light regimes of a closed forest as canopy as stated by Ashton (1995).

The presence of adequate number of seedling signifies better recruitment and germination of species in the forest. On the other hand, the dominance of established seedlings and saplings under the adult trees also affect the future composition of a community. Complete absence of seedlings and saplings of tree species in a forest is a clue towards its poor regeneration. These may be due to their poor seed germination and failure in the establishment of seedlings in a site. The lack of juveniles of some of the primary species has also been reported from tropical deciduous Sal (Sukumar et al. 1992). The species under 'not regenerating' condition might have occurred due to poor biotic potential of tree species which either affect the fruiting, production of seed or seed germination and is also influenced by the prevailing set of microclimatic conditions like temperature, light intensity, moisture availability, etc. Failure of successful conversion of seedling to sapling stage also brings to 'not regenerating' condition which may be due to unavailability of suitable micro-site and existing anthropogenic interference in the study site. Moreover, individuals in young stages of any species are more vulnerable to any kind of environmental stress and anthropogenic disturbance, which may lead to local extinction of the species in their natural habitat.

The diversity of species

Species diversity is an important aggregate indicator that reflects the effect of secondary forest restoration in tropical regions (Connell 1978; Wright 2002). The species richness of mature trees of *raru* was higher than that of saplings and seedlings. Change in species composition across mature and regenerating tree phases was more frequent in disturbed forest (Table 5).

Typical values for Shannon-Wiener diversity index (H') are generally between 1.5 and 3.5 in most ecological studies, and the index is rarely greater than 4. The Shannon-Wiener index increases as both the richness and the evenness of the community increase. The study result showed that from all stages (seedling to trees), Shannon-Wiener indices ranged 1.90-2.90. It indicates that tree stage represents the highest value where both species richness and evenness resulted in higher Shannon-Wiener index than other stages.

Species evenness refers to how equal the community in numerical sense. It defines how close in numbers each species in an environment is. The value ranges between 0-1. The less even of the species (with the presence of a dominant species) in a community is, the lower is the evenness value, and vice versa. From the data above, it is demonstrated that at most stage the evenness value was high except for the pole stage when the evenness is only 0.5.

From the study result, it was found that the Protection Forest in Bona Lumban area contains various timber species with economic value. However, its status as Protection Forest may not allow timber extraction within the area. Thus, the status also gives benefit for the conservation effort of *C. melanoxylon*. While in Riau the species disappeared quickly especially those at tree stage (Subiakto et al. 2017), we could see that different case likely happened in Bona Lumban Forest when protected status was given to the area and could clearly minimize the risk of exploitation. The variation in species richness and diversity for both tree species and seedlings could be attributed to the habitat heterogeneity represented by soil chemical properties, environmental factors, and human disturbance.

Table 5. Diversity, evenness, and species richness index for *Raru* growing at Bona Lumban Forest, North Sumatra, Indonesia at different life stage

Plant stage	Species diversity (H)	Evenness Index	Species richness Index	Number of species available
Seedling	2.53	0.94	3.64	15
Sapling	2.88	0.85	5.37	24
Pole	1.90	0.53	7.13	35
Tree	2.9	0.84	5.71	31

In conclusion, assessment of diversity and regeneration status of tree species is important for their sustainable utilization, management, and conservation. In this study, floristic composition in Bona Lumban forest is dominated by dipterocarp species. Regarding *raru*, the young regeneration of this species was lower compared to mature stage. It shows that the regeneration status of *raru* at the study area is fair and the future populations may be threatened if there is any major environmental stress or interference exerted by human activities. A systematic management plan is required for their conservation and sustainable utilization. The area status as protection forest seems to be effective to conserve the species by providing protection from overexploitation.

ACKNOWLEDGEMENTS

This research was supported by the Indonesian Ministry of Research, Technology and Higher Education through scheme Penelitian Dasar Unggulan Perguruan Tinggi (PDUPT) grant number 130/UN5.2.3.1/PPM/KP-DRPM/2018. Many sincerely go to local farmer in Bona Lumban for field assistance for this research.

REFERENCES

Appanah S, Turnbull JM. 1998. A review of Dipterocarps: taxonomy, ecology and silviculture. Center for International Forestry Research. Bogor.

Ashton PS. 1982. Dipterocarpaceae. Flora Malesiana Ser I. Spermatophyta 9: 237-552.

Ashton PS. 1995. Biogeography and ecology. In: Soepadmo E, Wong KM (eds.). Tree flora of Sabah and Sarawak. Sabah Forestry Department, Forest Research Institute and Sarawak Forestry Department, Kuala Lumpur.

Badan Pusat Statistik. 2016. Kabupaten Tapanuli Tengah Dalam Angka. Badan Pusat Statistik Kabupaten Tapanuli Tengah, Pandan. [Indonesian]

Barstow M. 2018. *Hopea forbesii*. The IUCN Red List of Threatened Species 2018: e.T36291A68070385. DOI: 10.2305/IUCN.UK.2018-1.RLTS.T36291A68070385.en.

Barstow M, Randi A. 2018. *Dryobalanops sumatrensis*. The IUCN Red List of Threatened Species 2018: e.T61998024A61998026. DOI: 10.2305/IUCN.UK.2018-1.RLTS.T61998024A61998026.en.

Barstow M. 2019. *Cotylelobium melanoxylon*. The IUCN Red List of Threatened Species 2019: e.T33070A68069829. DOI: 10.2305/IUCN.UK.2019-1.RLTS.T33070A68069829.en.

Chapin FS, Autumn K, Pugnaire F. 1993. Evolution of suites of traits in response to environmental stress. Amer Natur 142: S78-S92.

Cornell JH. 1978. Diversity in tropical rain forests and coral reefs. Science New Series: 199: 1301-1310

Curtis JT, McIntosh RP. 1950.The interrelations of certain Analytical and synthetic phytosociological characters. Ecology 31: 434-455.

Harrison RD, Hamid AA, Kenta T, Lafrankie J, Lee HS, Nagamasu H, Nakashizuka T, Palmiotto P. 2003. The diversity of hemi-epiphytic figs in a Bornean lowland rain forest. Biological J the Linnean Society 78: 439-456

Jumawan J, Flores FL, Aragan RT, Villamar JMC, Sagut JS, Taguse HC, Genecera J, Banas GG, Depamaylo AMV. 2015. Diversity assessment and spatial structure of mangrove community in a rehabilitated landscape in Hagonay, Davao Del Sur, Philippines. Adv Environ Sci Bioflux 7 (3): 475-482.

Khumbongmayum AD, Khan ML, Tripathi RS. 2005. Sacred groves of Manipur, Northeast, India: biodiversity value, status and strategies for their conservation. Biodiv Conserv 14: 1541-1582.

Lee SS, Yaakob NS, Boon KS, Chua LSL. 2002. The role of selected

animals in pollination and dispersal of trees in the forest: Implications for conservation and management. J Trop For Sci 14 (2): 234-263.
Matsuda H, Aso Y, Nakamura S, Hamao M, Sugimoto S, Hongo M, Pongpiriyadacha Y, Yoshikawa M. 2009. Antidiabetogenic constituents from the Thai traditional medicine *Cotylelobium melanoxylon*. Chem Pharm Bull 57: 487-494
Misra R. 1968. Ecology Work Book. Oxford and IBH, Calcutta.
Oostig HJ. 1942. An ecological analysis of the plant communities of Piedmont, North Carolina. Am Midl Nat 28: 1-126
Pasaribu G. 2009. Zat ekstraktif kayu raru dan pengaruhnya terhadap penurun kadar gula darah secara in vitro. Sekolah Pascasarjana IPB, Bogor [Indonesian]
Pooma R, Newman M. 2017. *Shorea leprosula*. The IUCN Red List of Threatened Species 2017: e.T33123A2833148. DOI: 10.2305/IUCN.UK.2017-.RLTS.T33123A2833148.en.
Phillips EA. 1959. Methods of vegetation study. Henry Holt. & Co., Inc. New York.
Rachmat HH, Subiakto A, Kesuma W, Susilowati A. 2018. Alarming call from Mursala Island, North Sumatra, Indonesia: The urgent task of conserving the previously reported extinct of *Dipterocarpus cinereus* Slooten. Biodiversitas 19: 2: 399-405
Ram J, Kumar A, Bhatt J. 2004. Plant diversity in six forest types of Uttaranchal, Central Himalaya, India. Curr Sci 86: 975-978.
Rao P. 1990. Community composition and tree population structure in a sub-tropical broad-leaved forest along a disturbance gradient. Vegetatio 88: 2: 151-162.
Rastogi A. 1999. Methods in Applied Ethnobotany: Lesson from the Field. Kathmandu, Nepal. International Center for Integrated Mountain Development (ICIMOD). Kathmandu, Nepal.
Reddy CS, Prachi U, Murthyand MSR, Sudhakar S. 2008. Quantitative Structure and Composition of Tropical Forests of Mudumalai Wildlife Sanctuary, Western Ghats, India. Taiwania 53 (2): 150-156.
Richards PW. 1996. The tropical rain forest: an ecological study. 2nd ed. Cambridge University Press, Cambridge.
Saxena AK, Singh JS. Quantitative profile structure of certain forest in the Kumaun Himalaya. Proc. Indian Acad Sci (Plant Sci) 91 (6): 529-549.
Sharma PD. 2003 Ecology and environment. 7th ed. Rastogi Publication, New Delhi.
Soerianegara I, Indrawan A. 1982. Ekologi Hutan Indonesia. Departemen Manajemen Hutan Fakultas Kehutanan Institusi Pertanian Bogor, Bogor. [Indonesian]
Soerianegara, Lemmens RHMJ. 1994. Plant Resources of South-East Asia 5. Timber Trees Major Commercial Timbers. Prosea Foundation, Bogor.
Subiakto A, Rachmat HH, Wijaya K. 2017. Dipterocarps: walk through the remnant forests in Riau-Sumatera. FORDA Press, Bogor.
Subiakto A, Rachmat HH. 2015. Exploration, collection and conservation of dipterocarps in Riau Islands. Pros Sem Nas Masy Biodiv Indon 1: 428-433.
Sukumar R, Dattaraja HS, Suresh HS, Radhakrishnan J, Vasudeva R, Nirmala S, Joshi NV. 1992. Long-term monitoring of vegetation in a tropical deciduous forest in Mudumalai, Southern India. Curr Sci 62: 608: 16.
Tripathi RS, Khan ML. 2007. Regeneration dynamics of natural forests—A Review. Proc Indian Natl Sci Acad 73: 167-195.
Woo SY, Thai HT, Park PS. Stand structure and natural regeneration of degraded forest land in the northern mountainous region of Vietnam. Landsc Ecol Eng 7: 251-261
Wright TSA. 2002. The Effect of the Halifax Declaration on Canadian Signatory Universities: a Tenth Year Anniversary Retrospect. Policy, Change and Environmental Sustainability in the University. [Dissertation]. University of Alberta, Edmonton, Canada.