Monitoring of ecosystem types in Lake Toba Region, North Sumatra

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Abstract. The Sumatra forest was estimated with high biodiversity and the second largest rate of deforestation after Kalimantan. However, the research about monitoring dynamics around the Lake Toba are still unknown. The aim of this research is to obtain information about changes in structure and composition of mountain forest in Lake Toba Region during 2018-2019. Vegetation survey in the old secondary forest around the Lake Toba Region, North Sumatra covers 0.9 ha area using 30 x 30m totalling 10 plots had been conducted in three villages, i.e., Jangga Dolok, Ambar Halim and Halado. The results showed that the highest Importance Value Index (IVI) of tree species during 2018 and 2019 in Jangga Dolok were Glochidion zeylanicum, Symplocos sp., and Schima wallichii; in Ambar Halim were Gordonia sp., Ardisia laevigata, and Xanthophyllum leave; in Halado were Lithocarpus sundaicus, Aporosa falcifera, and Gymnacranthera sp. The plots were dominated by vegetation with a diameter of 5-<10 cm. The density, the number of recruitment, and dead vegetation in Ambar Halim plot were the highest among the sites, followed by Jangga Dolok and Halado. The overall stand composition and structure of the plots in 2019 was mostly the same as in 2018.

1. Introduction
The Lake Toba Region consists of waters (lakes) and land (Samosir Island and the land surrounding the lake). The existence of Lake Toba's aquatic ecosystem is highly dependent on the existence of the surrounding terrestrial ecosystem. In addition, it is also known that there are endemic and endangered species around the Lake Toba area with 28 species from six genera (Balsaminaceae, Begoniaceae, Ericaceae, Gesneriaceae, Nepenthaceae, Orchidaceae) [1]. However, there has never been any research using permanent plot related to monitoring structure and composition of mountain forest in the Lake Toba area. The forests around the Lake Toba Region include mountain forest type areas with heights >1,000 m above sea level. The tree family of Fagaceae as the main characteristic of the forest type, besides Lauraceae, Sapotaceae, Sapindaceae, Myrtaceae, Meliaceae [2]. In disturbed areas, there are several species of Euphorbiaceae such as Macaranga sp. and Omalanthus sp. which reach large enough size (stem diameter >10 cm). The most species of the Euphorbiaceae are pioneer with high adaptation rates in various types of tropical forests, including in the Toba Mountain Forest types. The existence of the Lake Toba water ecosystem is very dependent on the existence of surrounding terrestrial ecosystem so that its existence should be maintained [3].
The forest area around Toba Samosir Regency has a diversity of species in the forest with standing stands, even though it is in another use area with a lower mountain forest type. The condition of the forest is well maintained because the community knows the importance of the forest area for their lives. Some previous studies that have been carried out around Lake Toba were land cover interpretations in Toba Samosir. Secondary dryland forest, forest plantation, dryland farming, shrubs, and water were also existing. Dryland Agriculture type was the most dominating land cover (36.89%) [4]. There were Pine (Pinus merkusii), Jelutung (Dyera costulata), and Puspa (Schima walichii) in Motung Village, Pasar Lumban Julu Village and Jangga Dolok Village as plus trees [5].

There are 48 species of potential plants found in the prospective Samosir New Botanical Garden [6] and there are 60 plant species from 40 families were identified on highland peats in Humbang Hasundutan, Toba [7].

A monitoring study of permanent plots had established in 2018 in three villages of Toba Samosir Regency, including Jangga Dolok Village, Ambar Halim Village, and Halado Village. This study aims to obtain information about changes in structure and composition of mountain forests in Lake Toba Region during 2018-2019.

2. Materials and Methods

2.1. Study sites
This research was conducted around the Lake Toba Region, North Sumatra. Re-measurement, data collection, and recruitment of plant species in 10 permanent plots cover of 0.9 ha area were carried out in three locations (table 1).

| Location | Geographic Position | Information |
|----------|---------------------|-------------|
| Jangga Dolok Village in Lumban Julu District, Toba Samosir Regency. | N 02° 33’ 28.0” - 02° 33’ 32.8” and E 099° 05’ 22.6” - 099° 05’ 38.1”. | There were five plots cover of 0.45 ha area with a height of 1160-1268 m above sea level (asl.). |
| Ambar Halim Village in Pintu Pohan Meranti District, Toba Samosir Regency. | N 02° 30’ 44.4” - 02° 30’ 10.8” and E 099° 13’ 41.6” - 099° 13’ 04.6”. | There were four plots cover of 0.36 ha area with a height of 1101-1166 m asl. |
| Halado Village, Pintu Pohan Meranti District, Toba Samosir Regency. | N 02° 33’ 41.3” and E 099° 16’ 59.1”. | There was one plot cover of 0.09 ha with a height of 915 m asl. |

The number of plots in each village is different due to differences of forest conditions in each village. The permanent plots were created in 2018 and monitoring research was carried out in 2019. The observation plots monitoring study had been conducted at Jangga Dolok Village, Ambar Halim Village, and Halado Village (figure 1).
2.2. Vegetation re-measurement (monitoring)
Vegetation re-measurements were carried out at three locations with 0.9 ha total area of ten plots (each of plot size was 30 x 30 m and each of subplot size was 10 x 10 m) [8]. Parameters measured from vegetation which have been signed by aluminium plate for tree numbering in the previous year, include the circumference of the trunk, the total height of the tree and the height of the free branch.

2.3. Data collection of new vegetation with a circumference of trunks > 15 cm (recruitment)
Data collections on new vegetation with a circumference of trunks > 15 cm (recruitment) include seedling, sapling and tree were carried out in each plot in the three study sites [8]. Vegetation was recorded by giving an aluminium numbering plate, collecting ecological evidence specimens, identifying the species and recording the position of x and y of the tree in the sub-plot. The total height of the tree and the free height of the branches were also measured. Specimens taken were then processed in alcohol and sent to Herbarium Bogoriense, Research Center for Biology-LIPI Cibinong for further identification.

2.4. Collection of dead, fallen and broken vegetation data
Vegetation data collections were carried out for fallen, dead and broken trees in each subplot in the plots of ten study sites.

2.5. Importance Value Index (IVI).
Vegetation data analysis was performed by calculating the Importance Value Index (IVI). The IVI calculation is intended to identify common species and it plays an important role in shaping forest ecosystems. This index is calculated by the following equation [9].

\[ Density (D_s) = \frac{\text{individual number of respective tree species}}{\text{total area of the plot}} \]

\[ Relative\ Density\ (RD_s) = \frac{\text{density of respective tree species}}{\text{all tree species density}} \times 100\% \]
3. Results and Discussion

3.1. Jangga Dolok Village

The five plots locations in this village were close to the settlement around 3 km. In general, changes in density (table 2), tree species with the highest IVI (table 3), number of recruitment and dead trees (table 4) in Jangga Dolok Village between 2018 and 2019 were not too different. *Macaranga triloba, Ficus* sp., and *Ficus obscura* grew during the recruitment process in 2019. These species were the pioneer or secondary species. In lowland Dipterocarp forests, species of recruitment that also found were *Macaranga* spp., *Mallotus* spp., *Ficus* spp., *Omalanthus* spp., and *V. arborea* [10].

### Table 2. Density in Jangga Dolok Plots 2018-2019

| Plot | Density (trees/ha) | 2018 | 2019 |
|------|--------------------|------|------|
| 1    | 611                | 533.33 |      |
| 2    | 1167               | 1122.22 |    |
| 3    | 1456               | 1511.11 |    |
| 4    | 1611               | 1611.11 |    |
| 5    | 1367               | 1366.66 |    |

### Table 3. IVI in Jangga Dolok Plots 2018-2019

| Plot       | Species            | 2018    | 2019    |
|------------|--------------------|---------|---------|
| Jangga     | *Glochidion zeylanicum* | 104.21  | 100.15  |
| Dolok      | *Symplocos* sp.   | 92.32   | 88.15   |
|            | *Schima wallichii* | 67.89   | 82.58   |

\[
Frequency (F) = \frac{\text{Observation plot number where respective tree species existed}}{\text{Total number of observation plot}}
\]

\[
Relative \, Frequency \, (RF) = \frac{\text{Frequency of respective tree species}}{\text{All tree species frequency}} \times 100\%
\]

\[
\text{Dominance} = \frac{\text{Basal area number of respective tree species}}{\text{Total area of the plot}}
\]

\[
Relative \, Dominance = \frac{\text{Dominance of respective tree species}}{\text{All tree species dominance}} \times 100\%
\]

\[
\text{Importance Value Index (IVI)} = RDs + RF + RD
\]
Table 4. Recruitment and Dead Trees in Jangga Dolok Plots 2018-2019

| Plot          | Recruitment Total | Species | Dead Total | Species                      |
|---------------|------------------|---------|------------|------------------------------|
| Jangga Dolok  | 31               | Antidesma montanum, Ficus obscura, Neonauclea calycina, Symplocos batakensis, Macadamia hildebrandii, Litsea sp, Adinandra dumosa, Macaranga triloba, Schima wallichii, Vaccinium varingiaefolium, Vernonia arborea, Ficus septica, Piper aduncum, Symplocos cochinchinensis, Symplocos fasciculate, Teijsmanniodendron coriaceum, Lithocarpus sundaeicus, Ficus sp., Dysoxylum densiflorum, and Adinandra dumosa, | 37   | Lithocarpus cyclophorus, Horsfieldia sp., Syzygium sp., Saurauia javanica, Barringtonia sp., Radermachera pinnata, Breynia sp, Actinodaphne sp, Litsea sp. Breynia sp, Euryia sp., Pinus merkusii, Lithocarpus encleisocarpus, Gordonia excelsa, Symplocos fasciculate, and Piper aduncum, Homalanthus populneus, Glochidion zeylanicum, and Symplocos sp. |

In figure 2, plot 1 and plot 2 had more dead plants than the recruitment, whereas in plot 3, plot 4, and plot 5 the number of dead plants was almost the same as the number of recruitments, because plot 1 and plot 2 were located closer to the settlements than other plots, so that anthropogenic factors may occur. These factors constitute the primary deterministic causes of species declines, endangerment and extinction: land development, overexploitation, species translocations and introductions, and pollution. The primary anthropogenic factors produce ecological and genetic effects contributing to extinction risk [11]. In this study the factors were land development and land conversion to enhance the community income. The fallen plants also occurred naturally in plot 1 and plot 2.
Plot 2 in Jangga Dolok 2018

Plot 2 in Jangga Dolok in 2019

Plot 3 in Jangga Dolok 2018

Plot 3 in Jangga Dolok in 2019
The relationship between the number of individuals per hectare and the diameter class was presented in Figure 3. The condition of the forest in Jangga Dolok Village is still well preserved because there are some trees which have diameter of more than 60 cm. The results of monitoring in 2019 were not different from the previous results in 2018 that all plots in Jangga Dolok Village
were still dominated by plants with diameter of 5-<10 cm in Figure 3, which indicates that the regeneration process is going well [10].
Plot 3 in Jangga Dolok 2018

Plot 3 in Jangga Dolok 2019

Plot 4 in Jangga Dolok 2018

Plot 4 in Jangga Dolok 2019
3.2. Ambar Halim Village
The four plot locations in this village were around 5 km from the settlement, in flat, hilly and hilltop areas with gentle slopes (10-15°) to steep (45°). Density (table 5), tree species with the highest IVI (table 6), number of recruitment and died trees (table 7) in Ambar Halim Village between 2018 and 2019 were almost the same. However, a decrease in density 2019 occurred in plot 3 while an increase in density 2019 was in plots 1, plot 2, and plot 4. The IVI value in the village of Ambar Halim generally declined in 2019 in almost every plot but these plant species were relatively common constituent.

Table 5. Density of Ambar Halim Plots in 2018 and 2019

| Plot | Density (trees/ha) | 2018 | 2019 |
|------|--------------------|------|------|
| 1    |                    | 1244 | 1244.44 |
| 2    |                    | 1700 | 1866.66 |
| 3    |                    | 1933 | 1844.44 |
| 4    |                    | 1878 | 1922.22 |
Table 6. IVI of Ambar Halim Plots in 2018 and 2019

| Plot            | Species       | IVI  | Species       | IVI  |
|-----------------|---------------|------|---------------|------|
| Ambar Halim     | Gordonia sp.  | 84.38| Gordonia sp.  | 81.32|
|                 | Ardisia laevigata | 69.31| Ardisia laevigata | 65.61|
|                 | Xanthophyllum leave | 42.81| Xanthophyllum leave | 41.84|

Table 7. Recruitment and dead trees in Ambar Halim Plots 2018-2019

| Plot            | Recruitment Total | Species | Dead Total | Species |
|-----------------|-------------------|---------|------------|---------|
| Ambar Halim     | 46                | Artocarpus heterophyllus, Palaquium rostratum, Schima wallichii, Sterculia longifolia, Actinodaphne angustifolia, Cinnamomum sintoc, Dysoxylum densiflorum, Elaeocarpus griffithii, Hopea cf.sangal, Phoebe elliptica, Symplocos batakensis, Adinandra dumosa, Elaeocarpus griffithii, Eurya sp., Gymnostoma sumatranum, and Schefflera aromaticana. | 34 | Symplocos lucida, Ardisia laevigata, Palaquium sumatranum, Gironniera subaequalis, Tetracera fagifolia, Magnolia liliifera, Ilex grandifolia, Bucklandia tricuspis, Prunus arborea, Alstonia angustifolia, Casuarina equisetifolia, Gordonia excelsa, and Bucklandia tricuspis |

The distribution of plant species in all plots in Halim Ambar Village (figure 4) showed that the number of dead plants was more than the recruitment in plot 3 only.
Plot 2 in Ambar Halim 2018

Plot 2 in Ambar Halim 2019

Plot 3 in Ambar Halim 2018

Plot 3 in Ambar Halim 2019
Figure 4. Tree species distribution in the plots of Ambar Halim Village in 2018 and 2019

Individuals with a diameter of 5-<10cm in diameter were most commonly found in all plots in Ambar Halim Village and trees with a diameter of more than 60cm are found in plots 1 and plot 2 were shown in figure 5.
Figure 5. Relationship between the number of individuals per ha and diameter class in Ambar Halim Village in 2018 and 2019

3.3. Halado Village
The plot was located around 30 km by crossing settlements, Eucalyptus grandis plantations, and some hills. There was only one sample plot because of the difficulty in finding a location for the size of the observation plot. The plot was in a very steep slope (> 45°). The density, IVI values, and the number of recruitments and dead trees were shown in table 8, table 9, and table 10, respectively. The distribution of plant species in Halado plot was shown in figure 6.

| Table 8. Density of Halado Plot in 2018 and 2019 |
|-----------------------------------------------|
| Plot | Density (trees/ha) | | |
|------|---------------------|---|---|
|      | 2018 | 2019 | |
| Halado | 1333 | 1344.44 | |

| Table 9. Important Value Index (IVI) of Halado Plot in 2018 and 2019 |
|-------------------------------------------------------------------|
| Plot | Species | IVI | Species | IVI |
|------|---------|----|---------|----|
| Halado | Lithocarpus sundaicus | 63.06 | Aporosa falcifera | 36.72 |
|        | Aporosa falcifera | 37.86 | Lithocarpus sundaicus | 33.46 |
|        | Gymnacranthera sp | 35.27 | Gymnacranthera sp | 32.18 |
Table 10. Recruitment and Dead Trees in Halado Plot 2018-2019

| Plot  | Recruitment                        | Dead                 |
|-------|------------------------------------|----------------------|
|       | Total Species                      | Total Species        |
| Halado| 9 Dacryodes griffithii, Garcinia rostrata, Neolitsea cassia, Trigoniastrum hypolleucum, and Xanthophyllum eurhythnum | 8 Lithocarpus bancanus, Memecylon edule, Syzygium zeylanicum, Cryptocarya laevigata, Aporosa falcifera, Gymnacranthera sp., and Xanthophyllum stipitatum |

Figure 6. Tree species distribution in Halado plot in 2018 and 2019

There was an increase in the number of tree densities per hectare and the number of recruitments was greater than the number of dead trees. However, there was a decrease in the IVI value in 2019. Individuals with a diameter of 5-<10cm in diameter were most commonly found in the plot in Halado Village as shown in Figure 7. The monitoring results in this plot were the same as those in the Jangga Dolok and Ambar Halim Villages, indicated that the plot in Halado Village was still dominated by plants with a diameter of 5-<10 cm.
Figure 7. Relationship between the number of individuals per ha and diameter class in Ambar Halim Village in 2018 and 2019

Tree species with the highest IVI at three study sites in 2019 were mostly the same as the previous year in 2018. The difference in the density (2018 and 2019) and the number of individuals between recruitment and dead trees were small. The plots were dominated by small trees which indicates that the regeneration process was going well. Forest dynamics have not seen significant changes due to the short time of monitoring schedule and anthropogenic factor that the forest was still well preserved by the community. In the mixed dipterocarp forest, Wanariset Semboja, East Kalimantan during the period 1980-2003 with three forest fires recorded 84% individual trees and 242 species of mortal, 1772 individuals who were classified into 188 species undergoing recruitment, where 123 species as new recruits by number 1128 individuals. Most of the recruits were recorded on pioneer or secondary species such as Macaranga spp., Mallotus spp., Ficus spp., Omalanthus spp., V. arborea, and etc. The primary species of recruitment that need to be noted were Diospyros elliptica and D. oblonga, Croton laevifolius, and Cananga odorata. Based on the concentration class diameter tree trunks note that recruitment generally takes place after the last major forest fires in 1997-1998 [10].

A monitoring ecosystem in Gunung Leuser National Park (TNGL) was conducted during 2000-2017 in North Sumatra that related to this study. The results showed that no significant changes occurred in these sites including tree composition and structure during 2000-2001, but by increasing year per year the changes in forest function occurred by land use change for agriculture and plantations. It showed that human alteration affected the changes especially for enhancement of community economics [12]. Monitoring of permanent plots in mixed dipterocarp forest, Bukit Bangkirai, East Kalimantan from 2013-2017 showed that the regeneration process was taking place in all species in the plot. The Euphorbiaceae and Lauraceae families were the main constituents of forest vegetation on Bukit Bangkirai, followed by the Fabaceae, Fagaceae and Myrtaceae families ready to replace the pioneer species [13].

Although no other previous study about monitoring of permanent plot in our study sites, but two previous studies that related to our study were identification of plus tree in Lumban Julu Regency, KPHL Model Unit XIV Toba Samosir in 2015 and potential plants in the prospective Samosir New
Botanical Garden in 2016. The result study in Lumban Julu Regency showed that the tree species with the highest IVI were Pine (\textit{Pinus merkusii}), Jelutung (\textit{Dyera costulata}), and Puspa (\textit{Schima wallichii}) in Motung Village, Pasar Lumban Julu Village and Jangga Dolok Village as plus trees, respectively [5]. From the results only \textit{Schima wallichii} or puspa was the same as vegetation with highest IVI compared to the results of our study in Jangga Dolok Village. There were 48 species of potential plants found in the prospective Samosir New Botanical Garden [6], including \textit{Schima wallichii}.

4. Conclusion
The highest Importance Value Index (IVI) of tree species in Jangga Dolok Village 2018 and 2019 were \textit{Glochidion zeylanicum}, \textit{Symplocos sp.}, and \textit{Schima wallichii}. The highest IVI of tree species in Ambar Halim Village 2018 and 2019 were \textit{Gordonia sp.}, \textit{Ardisia laevigata} and \textit{Xanthophyllum} \textit{leaf}. They were \textit{Lithocarpus sondaicus}, \textit{Aporosa falcifera} and \textit{Gymnacranthera} \textit{sp.} in 2018 and 2019 in Halado Village. The plots in the study sites were dominated by trees with a diameter of 5-10 cm. The density, the number of recruitment, and dead vegetation in Ambar Halim plot were the highest among the sites, followed by Jangga Dolok and Halado. The overall stand composition and structure of the plots in 2019 was mostly the same as the previous year (2018).

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