Multi-purpose riparian forest design for conservation and reduction of non-point source pollution in the Lake Toba catchment

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Abstract. The riparian forest as a filtering zone is the strategy to reduce non-point source pollution and increase forest cover around the catchment area. The aim was to establish a riparian forest design that is effective for the conservation and reduction of non-point source pollution which also giving beneficial socio-economic for the people. The method used were a literature study as basic reference and vegetation field surveys. The vegetation survey was carried out using nested plots at the river riparian area in the Lake Toba catchment. The vegetation seedling and saplings stand level samples were collected, and that biomass were analysed to determine N and P content. Each potential absorbing of N and P species was grouped based on its habitat. A total of 24 plant species were selected to develop a multi-purpose riparian forest design in the Lake Toba catchment. The design of the multi-purpose riparian model recommended the plantation for dry areas, semi dry areas, and wet areas. Plantation in the dry area consisted of multi-purpose tree species, in temporary dry areas can be planted ornamental perennial herbs, and wet areas comprised of species absorbing water pollutants.

1. Introduction

Lake Toba has a water body area of about 110,260 hectares and a catchment area of about 259,592 hectares, placing it as the largest lake in Indonesia [1][2]. Apart from being a tourist destination area, several areas in the Lake Toba area are also used for cultivation by the community, not only in the catchment area but also in the water body area [2][3]. Such conditions require comprehensive management so that the multi-purpose and benefits of Lake Toba can support each other optimally.

The current issue is that the water quality of Lake Toba is decreasing due to pollutants originating from domestic, agricultural land, and livestock [4][5]. The pollutants are carried by runoff and river water flow, not all of which enter the water body of Lake Toba, but some are deposited on the left and right of river cliffs and river riparian areas.

Environmental restoration of the water and soil from pollutants can be done with phytoremediation technology, which is a technology that uses the ability to decompose, destroy, move and stabilize pollutants using the help of plants. The plants used for the application of phytoremediation technology are based on the form of plant life in the form of terrestrial and hydrophytic plants, each of which has a
different role and ability [6][7][8][9]. One of the efforts to reduce lake pollution in the form of N and P elements is to prevent and handle pollution in situ and ex-situ by using the vegetation method [10]. The focus of treatment on the catchment area in particular in the form of the use of paddy fields which is allegedly a source of pollution and the river body as a drainage system of pollutants to the body of the lake[4][11]. The ability to absorb pollutants by various vegetation through plant physiological mechanisms is expected to contribute to reducing lake water pollution[7][10].

Forests in the Lake Toba catchment area, which should be able to act as water absorbers and reservoirs, have been degraded and changed due to over exploitation by anthropogenic activities. So that it affects the quality of the lake environment and the lake's aquatic ecosystem, including sedimentation, and the supply of water to the lake is disrupted [12]. Based on data of Directorate General of Forestry Planning and Environmental Management, Ministry of Environment and Forestry, estimated that the remaining secondary forest cover in the Lake Toba area was only 16.8% of a total area [5].

The riparian of rivers and lakes is a transitional ecosystem between terrestrial and aquatic which has a protective function with an important value to support hydrological processes and the health of water bodies. One approach to the management of a river and lake border is the method of planting vegetation enrichment which will function as a filtering zone from the terrestrial to the lotic and lentic environments to reduce erosion, sediment entrapment, reduce surface runoff and transform nutrients [13][14][15]. Therefore, the riparian forest development strategy is expected to assist efforts to increase forest area in the Lake Toba catchment area, which can function as conservation, cultivation, and environmental aesthetics. Environmental aesthetics are also important considering the Lake Toba area is a tourist destination. This study aimed to establish a design for the river riparian forest that is effective for the conservation and reduction of non-point source pollution in the catchment area, which also contributes to the socio-economic people in the area.

2. Methodology
2.1. Study site
The study was conducted at Lake Toba catchment area especially in Simalungun and Toba Samosir Regency, North Sumatera Province. This area is located at an elevation of 1,000-1,500 meter above sea level with the result that the type of forest ecosystem is sub-Montana forest.

2.2. Plant selection and survey vegetation
A literature study and a survey vegetation carried out plant selection to discover candidate plant for field planting. Beside searching and analysis the references through the literature, intensive personal communication to Dr Cynthia Henny, researcher at the Limnology Centre, Indonesian Life Science Institute was conducted to have the suggestion based on her experiences.

Survey vegetation through inventory activities at several riparian riversides in the Lake Toba catchment area were done to find location with the categories relatively undisturbed and had good forest cover as well as high diversity in biodiversity. The expected site’s conditions provide information on species diversity for the effectiveness of riparian vegetation as a filtering zone. The stages of field works were as follows:

1. Making nested plots with each subplot measuring 50mx50m for big tree level, 20mx20m for tree level, 10mx10m for sapling level, 5mx5m for pole level, 1mx1m for seedling level;
2. Taking out seedling/sapling parts i.e., leaves, stems, and roots of each plant species in the plots;
3. Analyzing the N and P content of vegetation parts in the laboratory of Indonesian Oil Palm Institute Medan. The information of N and P content were used for selecting species that have potential as bio-accumulator.
4. Sending herbarium samples from unknown species for identification to the Herbarium Bogoriensis, Indonesian Life Science Institute

Several preferred species obtained from literature studies and surveys were sorted and selected as the selected plant material to design composition the riparian forest model. Selection criteria proposed for sorting and selecting: as bio-accumulator (phytoremediation) based on the ability to absorb pollutant
elements N and P; as multi-purpose trees species (MPTS) and ornamental plant categories; as the habitus of big trees, trees, shrubs, shrubs/herbs, and grasses; the placement of plant based on location growing condition according to altitude, dry zone, semi-dry zone, wetland zone, and aquatic zone; and selection based on the local or native and non-invasive species.

The layout of plants species in the riparian forest model used a mix of various selected species. The diversity of these species were related to the variety of their life forms and biological habitats. In the arrangement using mixture species created a variety of riparian forest stand structures and stratification.

The development of the riparian forest model demonstrated a plot with 100 meters on both sides of the river. In view of the riverbank cross-sectional, the planting model was started from the river floodplain area (wet zone and semi-dry zone) to the dry zone. The width of the dry zone was 5 meters or based on local conditions, especially related to land ownership rights. Result and discussion

3. Methods

3.1. Field condition of Lake Toba catchment area

The average annual rainfall in the Lake Toba watershed ranges from 2 000 to 2 600 mm. The wettest months are October and November, with 260 mm of rain each month. June-July has the lowest monthly rainfall at 125 mm/month [16]. Evaporation from Lake Toba varies from 125.1 mm to 135.9 mm per month [17].

The source water of Lake Toba comes from 19 rivers (i.e., Sigubang, Bah Bolon, Guluan, Arun, Tomok, Sibandang, Halian, Simare, Aek Bolon, Mandosi, Gongpan, Bah Tongguran, Mongu, Kijang, Sinabung, Prembakan, Sipultakhuda, Silang) and become a reservoir. At the same time, Lake Toba contributes to Asahan’s river which travels along the East Coast [18]. The Asahan hydropower station uses Lake Toba's production to power a turbine[18][2].

Lake Toba's average monthly water level varies between 903.65 and 904.04 meters above sea level. September has the highest monthly water level of 904.62 meters above sea level, while February has the lowest monthly water level of 902.88 meters above sea level. Between 1986 and 1999, there was a 2.95 m difference in the water level of Lake Toba[18]. Acreman et al. [17] stated that the water level of Lake Toba had dropped by 2.5 meters between 1984 and 1987. This was because the output water was higher than input to the lake, which was related to the amount of rainfall. Changes in land cover may also contributed to a drop in Lake Toba's water level, but this is a minor factor [17].

3.2. The potential of plant species

The field study revealed that the vegetation composed of natural forests in the Lake Toba catchment area comprises species of wet mountainous tropical forests. Shrubs and fern are found in areas with steep and rocky slopes and around waterfalls. The mixed gardens are generally located on the edges of the forest. Study by Tampubolon [19] informed many species listed grow in natural forests, plantation forests, and mixed gardens. Marpaung [20] also provided information about MPTS plants and revealed that the people there had been planting these species for generations. Information on plant species based on [19] and [20] studies are presented in Table 1.

Table 1. The plant species information in the Lake Toba catchment based on study literature.

| No. | Sites | Plant species local name (scientific name) |
|-----|-------|------------------------------------------|
| 1.  | Secondary forests (including in forest plantation) | Keruing (*Dipterocarpus* sp) |
|     |       | Puspa (*Schima wallichii* Korth) |
|     |       | Kandis/Manggis hutan (*Garcinia celebica* L.) |
|     |       | Kayu raja |
|     |       | Sona, Angsana (*Pterocarpus indicus* Willd.) |
|     |       | Banyan |
|     |       | Cypress |
|     |       | Ekaiptus (*Eucalyptus* sp.) |
2. Mixed garden

- Alpokat (*Persia americana* Mill.)
- Aren (*Arenga pinnata* Merr.)
- Belimbing (*Averrhoa carambola* L.)
- Durian (*Durio zibethinus* Rumph. Ex Murray)
- Jeruk (*Citrus* sp.)
- Jambu klutuk (*Psidium guajava* L.)
- Rambutan (*Naphelium lallaceum* L.)
- Mangga (*Mangifera indica* L.)
- Nangka (*Artocarpus heterophyllus* Lamk.)
- Sirsak (*Annona muricata* L.)
- Bambu (*Bamboo* sp.)
- Cengkeh (*Syzygium aromaticum* L.)
- Coklat (*Theobroma cacao* L.)
- Dadap, Dapdap, Dakkap (*Erythrina subumbrans* Hassk. Merr.)
- Gamal (*Gliricidia sepium* Walp.)
- Jengkol (*Archidendron pauciflorum* Benth.)
- Kapok (*Ceiba petandra* (L.) Gaertn.)
- Kelapa (*Cocos nucifera* Linnaeus)
- Kemiri (*Aleurites moluccana* (L.) Willd.)
- Kopi (*Coffea* sp.)
- Mete (*Anacardium occidentale* L.)
- Petai cina (*Leucaena leucocephala* de Wit)
- Sawo (*Achras sapota* L.)

Sources: [19] [20]

Using 6 nested-plots, the Table 2 presents the plant species in the research site based on the field survey. The N and P analysis content on the biomass of several plant seedling and sapling samples are presented in Table 3. The analysis was only carried out on the plant species in the stand level of seedling and sapling.

**Table 2. Plants species listed based on the field survey.**

| Stand level classification | Species |
|---------------------------|---------|
| Trees                     | Bambu (*Bamboo* sp) |
|                           | Baringin/Beringin (*Ficus benjamina* L.) |
|                           | Aren (*Arenga pinnata* (Wurmb.) Merr.) |
|                           | Pinus (*Pinus merkusii*) |
|                           | Hoting (*Ficus subulata* Blume) |
|                           | Mangga (*Mangifera indica* L.) |
|                           | Hapas-hapas (Exbuclandia populnea (R.Br. Ex Griff.) R.W. Brown syn *Symingtonia populnea* Steem.) |
|                           | Kemiri (*Aleurites moluccana* (L.) Willd.) |
|                           | Tembisuh (*Eurya acuminata* DC) |
|                           | Jambuan tangkalak (*Bellucia pentamera* Naudin syn *B. axinanthera* Triana) |
|                           | Durian (*Durio zibethinus* L.) |
Table 3. The results of N and P content analysis on the stand level of seedling and sampling biomass

| No. | Species local name/scientific name | Leaf | Stem | Root | Other organs |
|-----|-----------------------------------|------|------|------|--------------|
|     | N (%)                             | P (%)| N (%)| P (%)| N (%)        | P (%)|
| 1.  | Kayu manis (Cinnamomum burmannii Blume) | 1.49 | 0.136| 0.61 | 0.169 | 0.65 | 0.119 |
| 2.  | Kayu manis (Cinnamomum burmannii Blume) | 1.25 | 0.108| 0.47 | 0.192 | 0.36 | 0.161 |
| 3.  | Macaranga triloba (Thunb.) Müll. Arg. | 1.14 | 0.083| 0.56 | 0.048 | 0.61 | 0.048 |
| 4.  | Dissochaeta sp | 1.44 | 0.092| 0.69 | 0.073 | 0.57 | 0.046 |
| 5.  | Pitu arus (Pternandra azurea (DC.) Burkill) | 2.11 | 0.060| 0.61 | 0.025 | 0.62 | 0.023 |
| 6.  | Symplocos lucida (Thunb.) | 1.28 | 0.192| 0.48 | 0.096 | 0.61 | 0.056 |
| 7.  | Tembissu (Eurya acuminata (DC.) Burkill) | 1.14 | 0.058| 0.67 | 0.033 | 1.55 | 0.033 |
| 8.  | Glochidion rubrum Blume | 0.86 | 0.163| 2.44 | 0.251 | 1.64 | 0.178 |
| 9.  | Glochidion rubrum Blume | 0.50 | 0.176| 0.11 | 0.276 | 1.37 | 0.150 |
| 10. | Ficus subulata Blume | 0.48 | 0.117| 0.38 | 0.064 | 1.59 | 0.050 |
| 11. | Ficus subulata Blume | 0.29 | 0.150| 0.45 | 0.087 | 0.85 | 0.067 |
| 12. | Durian (Durio zibethius) | 0.53 | 0.190| 1.06 | 0.188 | 0.64 | 0.169 |
| 13. | Bambu (Bambus sp) | - - | 0.50 | 0.312 | 0.70 | 0.075 | 0.72 | 0.043 |
| 14. | Bambu (Bambus sp) | - - | 0.87 | 0.473 | 0.63 | 0.155 |
| 15. | Symplocos lucida (Thunb.) | 0.87 | 0.362| 0.62 | 0.215 | 1.06 | 0.201 |
| 16. | Symplocos lucida (Thunb.) | 0.60 | 0.236| 0.64 | 0.232 | 0.54 | 0.234 |
| 17. | Symplocos lucida (Thunb.) | 0.29 | 0.150| 0.45 | 0.087 | 0.85 | 0.067 |
| 18. | Durian (Durio zibethius) | 0.53 | 0.190| 1.06 | 0.188 | 0.64 | 0.169 |
| 19. | Bambu (Bambus sp) | - - | 0.50 | 0.312 | 0.70 | 0.075 | 0.72 | 0.043 |
| 20. | Bambu (Bambus sp) | - - | 0.87 | 0.473 | 0.63 | 0.155 |

Description: 1) twigs, 2) root segment, 3) root weevil sources: Analyses result of the laboratory of Indonesian Oil Palm Institute (2019)
Based on the Table 3, the plant species that provides the highest N pollutant absorption effectiveness in the leaves was the *Pternandra azurea* of 2.11%. For the stems and roots parts were *Glochidion rubrum* with an effective absorption percentage of 2.44% and 1.64%, respectively. *Sipahit* plants had the highest percentage of P uptake in the leaves and roots, namely 0.362% and 0.234%, while for the stem, *Equisetum hyemale* was 0.473%. *Cinnamomum burmanii* and *Durio zibenthius* can absorb and store N and P, although they are not among the best species, such as *Pternandra azurea* and *Glochidion rubrum*. However, they can be chosen to establish a riparian model. The reason is that both species are perennial and MPTS types. *Sipahit* (*Thitonia deversifolia*) had a high P content in tissues so it can be used as a bio-accumulator plant. However, it is not recommended as a candidate because the plant is an invasive species. *T. diversifolia* in the Lake Toba catchment area is widely distributed. Referring to the results of Purwani’s research [21], this plant is rich in P nutrient so it can be used for green manure and compost.

The literature study informed the plant species that had the ability to absorb N and P as presented in Table 4.

| Type of plant habitat | Species of plants | Source |
|-----------------------|-------------------|--------|
| Dry land              |                   |        |
|                       | *Acacia aulococarpa* |        |
|                       | *Acacia auriculiformis* |        |
|                       | *Acacia crassicarpa* |        |
|                       | *Pilang (Acacia leucophloea)* |        |
|                       | *Acacia mangium* |        |
|                       | *Albizia chinensis* |        |
|                       | *Tekik (Albizia lebbeck)* |        |
|                       | *Weru (Albizia procera)* |        |
|                       | *Aru, cemara laut (Casuarina equisetifolia)* |        |
|                       | *Cemara gunung (Casuarina junghuniana)* |        |
|                       | *Kilu (Casuarina oligodon)* |        |
|                       | *Kacang gude (Cajanus cajan)* |        |
|                       | *Sonokeling (Dalbergia latifolia)* | Abdiyani and Irawan [22], |
|                       | *Keruing (Dipterocarpus grandiflorus)* |        |
|                       | *Dadap ayam (Erythrina variegata)* |        |
|                       | *Sengon laut (Falcataria moluccana)* |        |
|                       | *Turi (Sesbania grandiflora)* |        |
|                       | *Melinjo (Gnetum gnemon)* |        |
|                       | *Merbau Asam (Justia bijuga)* |        |
|                       | *Soga jambal (Peltophorum pterocarpum)* |        |
|                       | *Pilostigma malabaricum* |        |
| Wetlands              |                   |        |
|                       | *Tipha (Typha sp)* |        |
|                       | *Kana (Canna sp)* |        |
|                       | *Pisang-pisangan (Helleconia sp)* |        |
|                       | *Melati air (Echinodorus palifolius)* | Kurniawan and Henny [23], |
|                       | *Paperus (Cyperus paperus)* | Henny et al [24], |
|                       |                   | Henny et al. [25] |

3.3 Riparian forest model for Lake Toba catchment area

The river border ecosystem needs to be considered because it is a transitional boundary between terrestrial ecosystem and aquatic ecosystem that has an important protective function in the landscape to support hydrological processes and the health of water bodies [26]. When this ecosystem is overgrown by plant associations as riparian forests, it will function as a filtering zone from the terrestrial to the lotic environment to reduce erosion, trap sediment, reduce runoff and change nutrients [13][14][15]. In addition, the root system of river riparian vegetation can increase the strengthening of riverbanks [27][28][29].

Providing a river riparian forest in the Toba catchment area design is one of the strategic choices to improve the environment's quality. The expected purposes of the establishment of riparian forests are to reduce non-point source and increase green open spaces that can contribute to environmental conservation, improve the community's economy, and create environmental aesthetics. It promoted using of diverse plants species to establish riparian forest models so that composition of stands is heterogenous and multi-purpose [30][31][32][33].
The selection of suitable species for the biogeography condition of the Lake Toba catchment based on developed criteria has been done. The criteria developed were the ability to absorb pollutant elements N and P as bio-accumulator (phytoremediation); MPTS (multi-purpose trees species) types, and ornamental plant types; life forms/habitus (big trees, trees, shrubs, shrubs/herbs, and grasses), habitats where they grow (altitude, dry zone, semi-dry zone, wetland zone, and aquatic zone), local/native species, and non-invasive species. Species preference analysis used the species database presented in table 1, table 2, table 3, and table 4. The analysis resulted in 24 plants species being promoted to establish a riparian forest model in the Lake Toba catchment. The results of the species analysis are presented in Table 5.

Table 5. Various vegetation species were used to construct the riparian forest model.

| No. | Species | Description | Height (m) | Habitat |
|-----|---------|-------------|------------|---------|
| 1.  | Papirus (Cyperus papyrus L.)\(^1\)\(^3\) | herb | 2 | Wl |
| 2.  | Melati air (Echinodorus palfilus)\(^1\)\(^3\) | herb | 0.3 | Wl |
| 3.  | Tpya (Typha sp)\(^1\)\(^3\) | herb | 2 | Wl |
| 4.  | Pisang-pisangan (Heloconia sp)\(^1\)\(^3\) | herb | 1 | S |
| 5.  | Kana (Canna sp)\(^1\)\(^3\) | herb | 1 | S |
| 6.  | Alamanda (Alamanda cathartica L.)\(^1\)\(^3\) | shrub | 2 - 6 | S |
| 7.  | Kacang gude (Cajanus cajan (L.) Millsp.)\(^1\) | shrub | 4 | D |
| 8.  | Hoting (Ficus subulata Blume)\(^2\) | shrub-medium tree | 15 | S |
| 9.  | Turi (Sesbania grandiflora Nees)\(^1\) | small tree | 10-15 | S-D |
| 10. | Rukam (Flacourtia rukam)\(^1\) | medium tree | 5-20 | S-D |
| 11. | Modang kuning, Simarnakki (Vernonia arborea Buch. Ham.) | tree | 15-20 | D |
| 12. | Aren (Arenga pinnata (Wurmb.)\(^3\) Merr.) | medium tree | 5-15 | D |
| 13. | Kayu manis (Cinnamomum burmanni Blume)\(^2\) | medium tree | 5-15 | D |
| 14. | Melinjo (Gnetum gnemon L.)\(^1\)\(^2\) | medium tree | 15 | D |
| 15. | Dadap (Erythrina variegata L.)\(^1\) | small-medium | 15-20 | D |
| 16. | Sengon (Falcataria moluccana Miq.)\(^1\)\(^2\) | medium tree | 15-40 | D |
| 17. | Alpokat (Persea americana P. Mill.)\(^2\) | Medium tree | 9-20 | D |
| 18. | Mayang durian (Palaquium hexandrum (Griff.) Baill.) | tree | 20-40 | D |
| 19. | Kemenyan (Styrax sumatrana J.J.Sm.)\(^2\) | medium-big tree | 12-30 | D |
| 20. | Pete (Parkia speciosa Hassk.)\(^2\) | tree-big tree | 15-40 | D |
| 21. | Kemiri (Aleurites moluccanus (L.) Willd.)\(^2\) | big tree | 30 | D |
| 22. | Durian (Durio zibethinus L.)\(^2\) | big tree | 25-40 | D |
| 23. | Mangga (Mangifera indica L.)\(^2\) | Tree-big tree | 30 | D |
| 24. | Sampinur (Dacrycarpus imbricatus (Blume) de Laub)\(^2\)\(^4\) | big Tree | 50 | D |

Description: habitat: D = dry zone; S = semi dry zone; Wl = wetland zone.

Uses: 1) plants that have the potential to absorb N and P, 2) multi-purpose trees species, 3) ornamental species, 4) endemic/native species.

The botanical description of the species (habitats and height) is traced from Heyne [34], and trusted plant database websites such as Useful Tropical Plants (http://tropical.theferns.info/), and Plantamor (http://plantamor.com/).

There were found 11 plant species as phytoremediation [22][23][24][25] planted in the wetlands zone, semi dry zone, and dry zone. These plants were as herbs, shrubs, and trees. Besides as phytoremediation, some of these species are also ornamental plants because of flowering and beauty performance, namely...
Papirus (Cyperus papyrus L.), Melati air (Echinodorus palifolius), Typa (Typha sp), pisang-pisangan (Helleconia sp), Alamanda (Allamanda cathartica L.), and Dadap (Eryhrina variegate L.). Meanwhile, the plants species belonging to the MPTS group are already known and used for medicine, spices, fruit, and wood by the local community[35][36][37]. A rare endemic plant, Styrax sumatrana is also planted. This species produces a latex called kemenyan which in the past was a local precious commodity[38]. 

Arenga pinnata is a useful plant, not only for local beverage ingredients because of produce a sap but also for soil conservation because of its strong root system[37][39].

Based on the selected species presented in table 5, the study designed their compact placement in a riparian forest model. The layout of plant species starts from floodplains, riverbanks, until dry zones. The dry zone boundaries of the planted rivers are 5 meters wide or based on local conditions, especially related to land ownership rights. Implementing the model uses a demonstration plot with a length of 100 meters long on either side of the river. The riparian forest model layout is shown in figure 1. The layout of the selected species in the mixed planting system takes into observing their botanical characteristics. Descriptions of the botanical characteristics of each species were got through a literature study. Information about the maximum growth height of a species is an important property in the characteristics of life forms used to plan mixed planting patterns for riparian forest models. Based on plant high information, the selected plant’s species were grouped into five canopy stratifications, namely 40 meters, 30 meters, 20 meters, 10 meters, and under 10 meters. Plants 30 and 40 meters tall are classified as dominant trees. Dominant group plants are planted at wide distances to provide light and growing space for other groups’ species. Plants that have a canopy with a height of below 40 and 30 meters, as medium trees, shrubs, and herbs, are planted in a mix of the dominant group trees. The mixed planting arrangements using various plant species resulted in a heterogeneous stand with layered crown stratification such as in tropical natural forests (presented in figure 2).

![Figure 1](image_url)

**Figure 1.** The layout of the distribution of the selected species in the riparian forest model. (Note: the yellow line is the top edge of the streambank slope).
Figure 2. Designed cross-sectional view of diverse stand structure and layered stratification of riparian forest model at old growth stage.

Its promoted trees and other vegetation in this model to support several functions, namely hydraulic functions as riverbank reinforcement, ecological functions as habitats and suppliers of fauna feed substrates, environmental regime stabilizers, and of course, related to entrapment and remediation[33][40][41]. Phyto-remediation such as nitrate in the riparian zone is a complex interaction of plants, soil, hydrology, and microbes. Related to the removal of non-point source pollution by riparian vegetation is through the deposition of runoff sediments and 50-80% reduction of pollutants in the sediments[29]. The effectiveness of riparian forests in reducing non-point source pollution is related to the width, ages and composition of the forest, and grasses-herbaceous species existence[29]. Perennial vegetation such as trees play a role in the storage of pollutant nutrients in its wood.

4. Conclusion

The riparian forest model in this study is expected not only to be environmentally beneficial through reducing non-point source pollution, but also to be economically beneficial and increase the aesthetic of the environment. There are 24 species which is promoted to build a model of river riparian forest in the Toba catchment.

Several plant species function as phytoremediation of N and P elements such as tipha (Typha sp), pisang-pisangan (Helleconia sp), melati air (Echinodorus palifolius), paperus (Cyperus paperus), Canna sp, Allamanda cathartica L., Cajanus cajan (L.), Sesanbia grandiflora Nees, Gnetum gnemon L., Erythrina variegata L., Falcataria moluccana Miq. In addition, there are also plant species that can function as riverbank reinforcement as well as MPTS, namely Arenga pinnata. There are also other MPTS plants such as Avocado, Durio, Kemiri. Some of these species of plants also have good performance for aesthetics because of flowering such as Canna sp, Allamanda cathartica, and Echinodorus palifolius. Styrax sumatrana as a native species of Sumatra is also planted so that the development and conservation of native species can also support the establishment of a multi-purpose riparian forest model. Mixed planting of riparian forest model with various selected species compositions is form a heterogenous stand forest structure and layered canopy stratification.
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