Diversity, Vegetation Structure, Estimated Biomass and Carbon Stock in The Site of Limboto Lake of Gorontalo Regency

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Abstract *–The development of Limboto Lake Site as the pilot area of Gorontalo Geopark is one step in rescuing the lake. This research aims to analyzed the vegetation structure, estimate biomass, and assess the carbon stock value of the vegetatio at the Limboto Lake site. This study employed a purposive sampling method. Important Value Index, a measure used to evaluate plant vegetation structure, was calculated based on Realtive Density, Relative Dominance, and Relative Frequency values. Biomass estimation and carbon stock assessment were conducted using allometric equations. The study's finding showed that the vegetation surrounding Soekarno's landing area exhibited the highest IVI (sawlogs) scores for Swietenia mahagoni tree at 82.86%, Leucaena leucocephala saplings at 79.56%, and Manihot esculenta seedlings at 46.33%. Leucaena leucocephala consistently achieved the highest IVI score within the Limboto Lake area with a score as high as 76.90%, followed by Leucaena leucocephala on the sapling level with a score as high as 70.03%, and Nauclea orientalis on the seedling level with a score as high as 53.06%. Swietenia mahagoni, Samanea saman, and Leucaena leucocephala are three species with stems that predominate at the sawlog level and sapling, and these stems have high carbon absorption values.*

Keywords: *Biomass, Carbon Stock, IVI, Limboto Lake, Vegetation structure*

INTRODUCTION

The location of Limboto Lake is among the 26 places suggested by the Provincial Government of Gorontalo for the Geopark's pilot area. Limboto Lake is one of the natural resource owned by the Province of Gorontalo. Currently, the lake is in a very concerning state due to silting and depreciation, which threatens its future existence. The Limboto Lake's shrinking size affects both its water-holding capacity and the habitats of aquatic organisms. This situation could lead to flooding and the loss of endemic species' habitats (Akuba & Biki, 2009; Lihawa & Mahmud, 2017). The silting in Limboto Lake is caused by the sedimentation from forest erosion, household waste, water hyacinth, and non-ecofriendly fish farming (Mahmud et al., 2020).

The development of Gorontalo Geopark, centered around Limboto Lake, offers multiple benefits. Geopark is one of the ways to improve the condition of the narrowing Limboto Lake while also contributing to tourism. The announcement by the provincial government of Gorontalo that Limboto Lake will eb a Geopark pilot area brings new hope for lake management. This declaration will draw attention from local and central governments, particularly those concerned with lake management and sustainability (Khoshraftar, 2013; Sunan et al., 2020). This positive impact will aid critical condition of the Limboto Lake site, affected by silting, and will also benefit the surrounding community's income.

The growth of the Limboto Lake site and its surroundings as the Gorontalo Geopark's pilot area has been investigated from various perspectives, including biodiversity, particularly the plantation life in the area. The vegetation plays an important role in maintaining the lake's sustainability. The vegetation surrounding Limboto Lake serves an ecological purpose for the lake. Baderan and Angio's (2019) study "Measuring the Biodiveristy Index from a Geo-Site in Gorontalo Province (A pilot project of Gorontalo Geo-Park)" investigated the biodiversity of plants in the vicinity of Limboto Lake Site, which covered its immediate surroundings. The study identified 739 plant families dispersed across 8 (eight) points in the Gorontalo Geo-Park pilot area, according to Baderan and Angio's (2019) research. Each Otanaha Fortress holds 50 families, each of which contained Sterculia foetida, the species with the highest market value in the world.

The local vegetation pattern can provide insight into a plant's significance within a specific environment. The balanced ecosystem in a region can generally benefit from vegetation. This effect depends on the vegetation type and growth pattern in a specific area (Safitri & Astiani, 2017; Hairah et al., 2011; Indriyanto, 2006; Yuliawati et al., 2016). The Limboto Lake Site's vegetation structure demonstrates that the region's particular vegetation type plays a crucial role (Suryandari & Sugianti, 2017). This can be drawn as each species exhibiting a variety of significant values indices due to the influence of varied environmental conditions. Information about the vegetation types with fairly high important value index indices can guide the selection of suitable vegetation for the Limboto Lake Site.

The vegetation surrounding Limboto Lakes serves multiple purposes, such as reducing air pollution, preventing erosion, and providing aesthetic value for tourist destinations. Plants require carbon dioxide (CO^2) for photosynthesis, which aids in reducing atmospheric carbon dioxide levels (Rinjani et al., 2016). As a method of mitigating climate change, vegetation is crucial in lowering the greenhouse effect. This is achieved through a sequestration mechanism, where plants absorb carbon from the atmosphere and store it in biomass (Hairiah et al., 2010; Naharuddin, 2017). The Limboto Lake Site experiences variations in carbon absorption by vegetation. High absorption values are often found in plants with high carbon stocks and biomass. The higher a plants capacity to absorb carbon, the greater its role in reducing carbon dioxide and improving air quality in the area.

MATERIALS AND METHODS

1. Materials

The materials used in this study were all of the standing vegetation in each transect path and observation plot. Identification of vegetation found in all the plots was carried out using multiple.

Reference guides (Culmsee et al. 2011; Cappers & Bekker, 2013; POWO, 2022). The references for herbarium were specimens from Herbarium Purwodadiense and Kew's Herbarium (The Herbarium Catalogue, 2022).

The tools employed in this study are: Phi band to measure the sampling plot; Global Positioning System (GPS) to determine the coordinate; tree calliper to measure the diameter of the stem; PE Rope (2 mm) to demarcate the sampling unit; Stake as the marker of the sampling unit; Knife or cutter and plastic bag to collect the soil samples; Camera to document the research activities; Tally sheet to record and categorize observed data; Counter to count the tree numbers; Stationary to write the measurement data; Software programs to analyse the data.

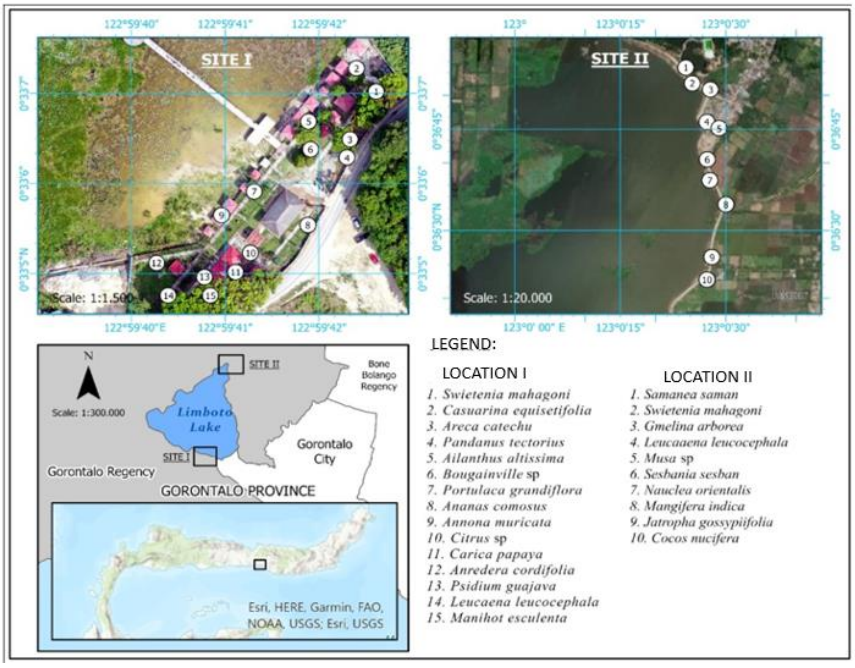


Figure 1. Map of the Research location

2. Methods

The study was conducted in two primary locations: The Soekarno Landing Museum and the vicinity of Limboto Lake in the Gorontalo Regency. The data collection location in the Landing Area of Soekarno is situated at the coordinates N 00°33’5,41” and E 122°59’40,87”, and the area of Limboto Lake is positioned at coordinates of N 00°36’50,30” and E 122°02’28,10” (Figure 1).

The survey method used in this study combined a qualitative descriptive research design. The purposive sampling model using a previously determined transect scheme was the sampling strategy used in this study. The Allometric equation by Kettering et al. (2001) was used in Manyo'e's (2018) study to calculate the tree's biomass without using destructive sampling (without harvesting). Track or transect methods were used to collect direct data from the research area. In each location of the research, three tracks were determined. Each track has a plot or sample map. The sampling unit's size is determined by the National Standard of Indonesia (SNI) for vegetation level in 2011 and is as follows:

a. Size 20 m x 20 m for sawlog level (woody vegetation with diameter ≥ 20 cm);
b. Size 10 m x 10 m for pole level (woody vegetation with diameter 10 cm to < 20 cm);
c. Size 5 m x 5 m for sapling level (vegetation with diameter 2 cm to < 10 cm); and
d. Size 2 m x 2 m for seedling level (vegetation with diameter < 2 cm and height ≤ 1.5 m).

3. Vegetation Structure

The data on vegetation which had been collected were analyzed to gain the values of Relative Density (RD), Relative Dominance (RD_o), Relative Frequency (RF) to obtain Important Value Index (IVI), Diversity index, Similarity index from each location of this research. To analyze the trees vegetation, the IVI value consisting of RD, RD_o, and RF was analyzed based on the reference book entitled Forest Ecology (Indriyanto, 2006) based on the formula of Ellenberg & Dombois (1974):

a. Density (D) = $\frac{\text{Number of the Individual}}{\text{the Area of Sample Square}}$

Relative Density (RD) = $\frac{D \text{ of a species}}{\text{the Total } D \text{ for all species}}$ x 100%

b. Frequency (F) = $\frac{\text{the total of sampling unit in which a species occurs}}{\text{the Total for sampling unit}}$

Relative Frequency (RF) = $\frac{F \text{ of a species}}{\text{the Total } F \text{ for all species}}$ x 100%

c. Dominance (D_o) = $\frac{\text{Total basal cover of individual species}}{\text{the Total for sampling unit}}$

Relative Dominance (RD_o) = $\frac{Do \text{ of individual species}}{Do \text{ for all species}}$ x 100 %

d. Important Value Index (IVI)
Important Value Index (IVI) in a species can explain the effects or role of a vegetation species in a community. The higher the important value index, the higher the role of the species for the ecosystem. To calculate the IVI, the following formula can be applied:
IVI = RD + RF + RD_o

4. The Value of Biomass

The values of a biomass of a tree can be done by implementing a non-destructive sampling method which refers to the result of Diameter Breast Height (DBH) or measuring the diameter of the trunk or bole of a standing tree. The biomass of a tree can be calculated by using the Allometric equation (Kettering, et al., 2021) presented in the following:

$$BK = 0.11\ \rho\ D^{2,62}$$

Note:
BK : Tree Biomass (in Kg)
ρ : Density (g/cm^3)
Obtained from the database of Wood Density Database of Trees World Agroforestry
D : Diameter as high as the breast-height (130 cm from the ground surface)

5. Value of the Carbon Stock

The carbon stock was calculated based on the SNI (2011) as presented in the following:

CB= B x % C Organic

Note:
CB : Carbon content in biomass (kg)
B : Total Biomass (kg)
%C Organic : the percentage of the carbon content obtained from the result of laboratory measurement that is 0.47.

6. The Value of Absorption Carbon

The analysis of the absorption carbon was calculated by using the data of carbon stock with a formula used by IPCC (2006) as presented in the following:

EC = 3.67 X CLC-D

Note:
EC : Carbon Absorption
3.67 : *Ratio atomic carbon dioxide* towards Carbon: 44/12(tCO_2 e/ton C)
CLC-D : Carbon Stock

RESULTS AND DISCUSSION

1. The Vegetation Structure and IVI in the Landing Area of Soekarno

Based on the field's direct measurements,, various vegetation types that were present in the Soekarno Landing Area had distinct values for relative density, relative frequency, and relative dominance at different plant levels. A different important value index was acquired by the plant in Soekarno's Landing Area at each level. At the sawlog, sapling, and seedling level, the highest IVI was reached by Swietenia mahagoni (82.86%), Leucaena leucocephala (79.56%), and Manihot esculenta (46.33%) respectively (Table 1, Table 2 and Table 3).

Table 1. Vegetation Structure and IVI at Sawlog Level in the Landing Area of Soekarno

Species	RD (%)	RF (%)	RDo (%)
Swietenia mahagoni	29.03	23.08	30.75
Casuarina equisetifolia	16.13	15.38	13.21
Areca catechu	19.35	30.77	11.07
Pandanus tectorius	12.90	7.69	8.87
Ailanthus altissima	22.58	23.08	36.11

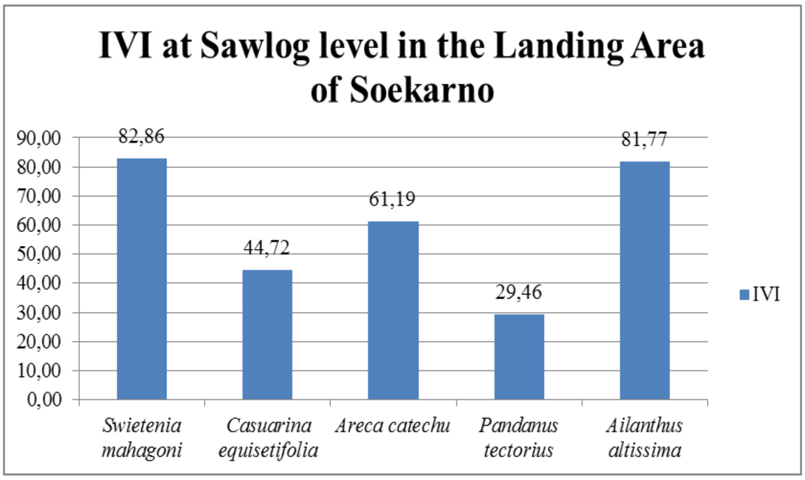


Figure 2. IVI at Sawlog level in the Landing Area of Soekarno

Table 2. The Vegetation Structure at Sapling Level in Landing Area of Soekarno

Species	RD (%)	RF (%)	RDo (%)
Swietenia mahagoni	20.59	20.00	20.91
Areca catechu	11.76	20.00	11.37
Carica papaya	23.53	13.33	22.03
Annona muricata	14.71	26.67	15.53
Leucaena leucocephala	29.41	20.00	30.15

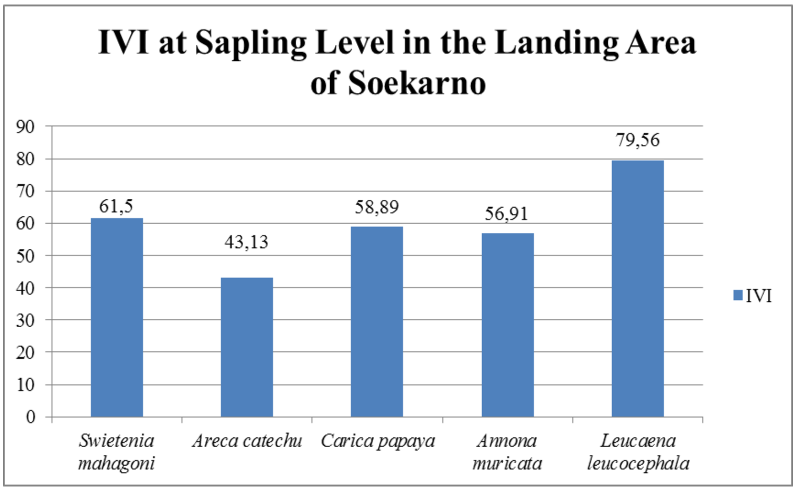


Figure 3. IVI at Sapling level in the Landing Area of Soekarno

Table 3. The Vegetation Structure at Seedling Level in Landing Area of Soekarno

Species	RD (%)	RF (%)	RDo (%)
Ananas comosus	13.04	7.69	12.33
Psidium guajava	15.94	11.54	14.52
Leucaena leucocephala	10.14	19.23	10.70
Bougainvillea sp	7.25	7.69	7.19
Carica papaya	13.04	7.69	12.89
Anredera cordifolia	8.70	7.69	9.17
Citrus sp	11.59	11.54	12.84
Portulaca grandiflora	7.25	7.69	6.32
Manihot esculenta	13.04	19.23	14.06

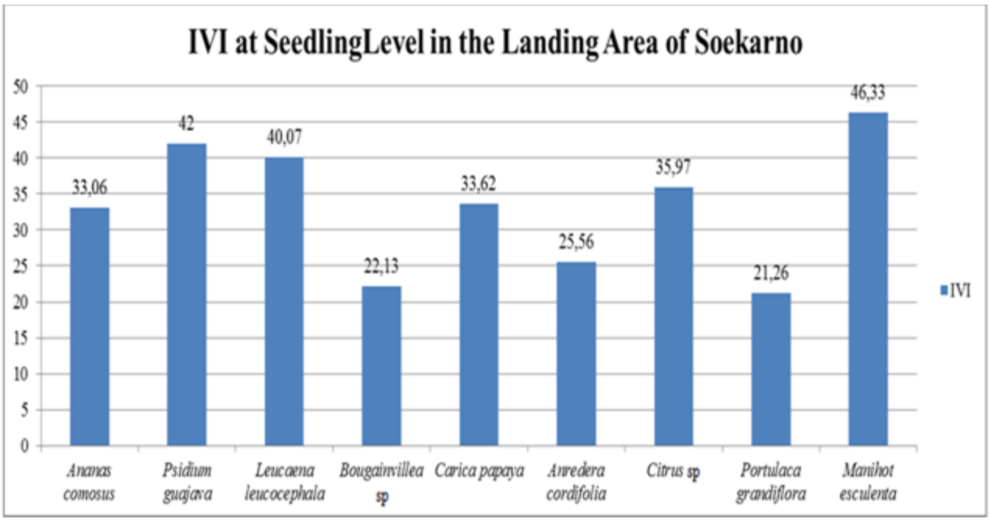


Figure 4. IVI at Seedling level in the Landing Area of Soekarno

2. The Vegetation Structure and IVI in the Area around Limboto Lake

Around the Limboto lake, the vegetation has distinct IVI at each level. *Leucaena leucocephala* (76.90%), *Leucaena leucocephala* (76.90%), and *Nauclea orientalis* (53.06%), respectively, had the highest IVI around Limboto Lake at the sawlog, sapling, and seedling levels (Table 4, Table 5 and Table 6). Based on the aforementioned information, it is apparent that *Leucaena leucocephala* has the highest IVI of all the plants that are native to the Limboto Lake region.

Table 4. Vegetation Structure at Sawlog Level in the Area around Limboto Lake

Species	RD (%)	RF (%)	RDo (%)
Leucaena leucocephala	25.64	27.78	23.48
Swietenia mahagoni	17.95	16.67	19.29
Samanea saman	23.08	22.22	23.34
Sesbania sesban	12.82	16.67	11.46
Gmelina arborea	20.51	16.67	22.43

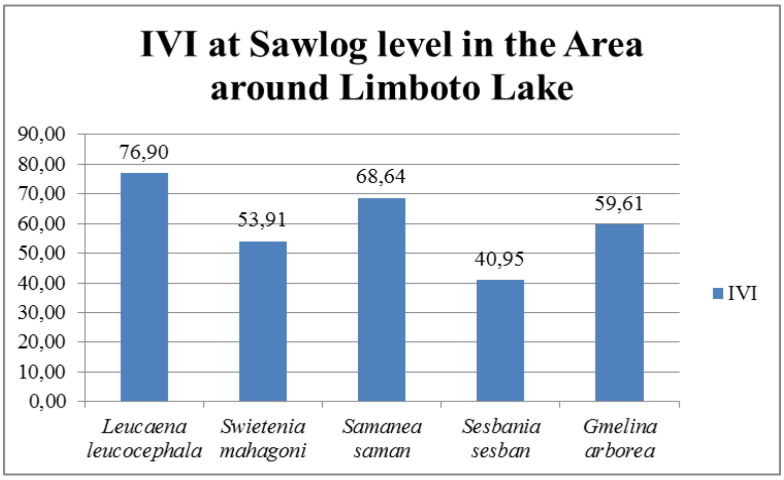


Figure 5. IVI at Sawlog level in the Area around Limboto Lake

Table 5. The Vegetation Structure at Sapling Level in the Area around Limboto Lake

Species	RD (%)	RF (%)	RDo (%)
Leucaena leucocephala	22.92	23.81	23.30
Swietenia mahagoni	20.83	19.05	20.57
Samanea saman	14.58	14.29	14.30
Sesbania sesban	18.75	19.05	19.85
Gmelina arborea	22.92	23.81	22.00

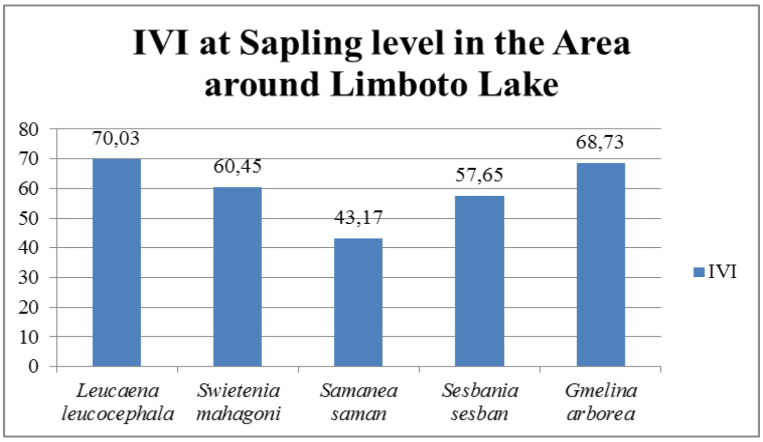


Figure 6. IVI at Sapling level in the Area around Limboto Lake

Table 6. The Vegetation Structure at Seedling Level in the Area around Limboto Lake

Species	RD (%)	RF (%)	RDo (%)
Leucaena leucocephala	10.92	15.63	10.90
Musa sp.	13.45	15.63	13.70
Nauclea orientalis	16.81	18.75	17.50
Mangifera indica	14.29	12.50	14.30
Cocos nucifera	16.81	15.63	15.77
Jatropha gossypiifolia	15.97	12.50	16.12
Swietenia mahagoni	11.76	9.38	11.75

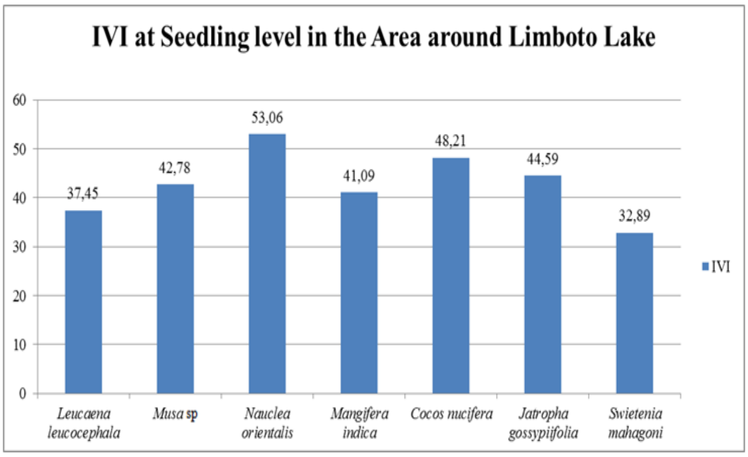
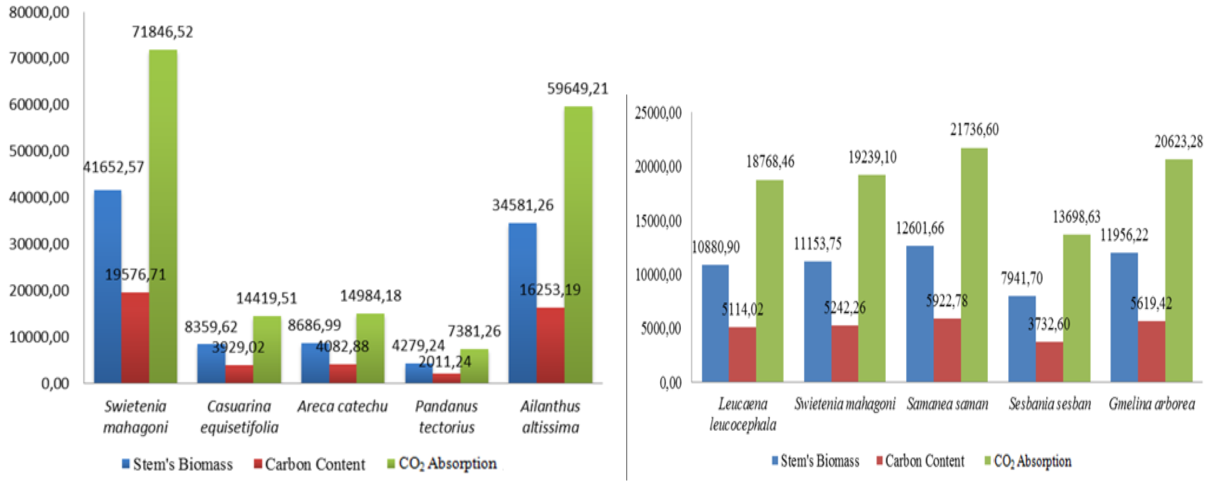


Figure 7. IVI at Seedling Level in the Area around Limboto Lake

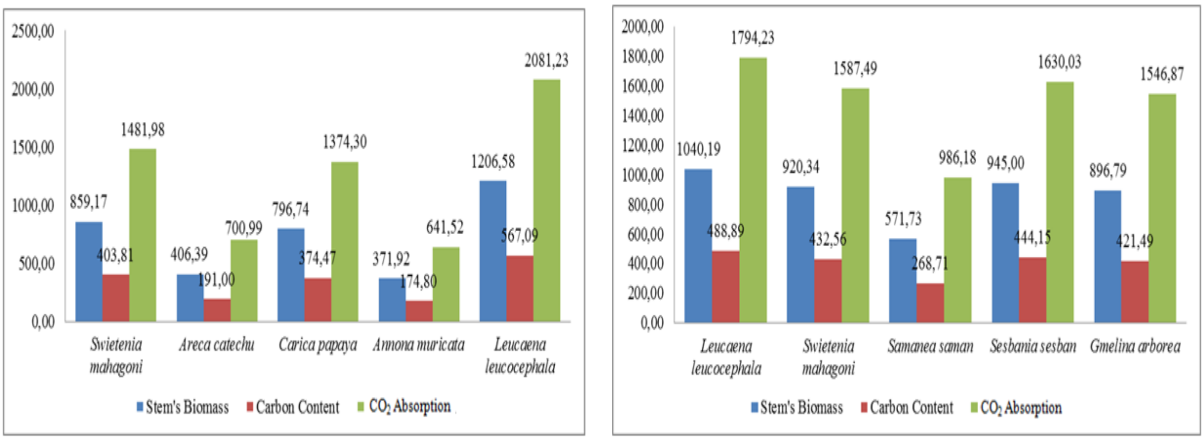
Thus it can be inferred that *Leucaena leucocephala* is the dominant species around the Limboto Lake. This is in line with Sunandar et al. (2019) who stated that the Important Value Index (IVI) required to reveal the mastery level of each kind of trees in one stand. The higher the Important Value Index (IVI) of a species, the higher the mastery level in a community where this species is growing. Hong et al. (2017), who asserted that a species of plant can be the main player if the Important Value Index reached >10% in seedling and sapling levels and that the Important Value Index at the pole and sawlog levels should reach as high as 15%, supported this claim.

According to the findings of this study, a number of species have the greatest dominance in each region, achieving a very high level of carbon absorption. At sawlog level, species with the highest biomass value, carbon content, and CO_2 absorption are *Swietenia mahagoni* (Figure 8a) and *Leucaena leucocephala* (Figure 8b) at sapling level. *Samanea saman* (Figure 9a) and *Leucaena leucocephala* (Figure 9b) are the species with the highest biomass value, carbon content, and CO_2 absorption in the vicinity of Limboto Lake at the sapling level.



(a) (b)

Figure 8. The Value of Biomass, Carbon Content, and CO2 Absorption at Sawlog Level in the research locations; a) Landing Area of Soekarno; (b) Around the Limboto Lake



(a) (b)

Figure 9. The Value of Biomass, carbon content, and CO^2 absorption at the Sapling level in the research locations; a) Landing Area of Soekarno; (b) Around the Limboto Lake.

The area around Limboto Lake showed a higher average score than in the Landing Area of Soekarno, according to the results of the C-Organic Test in a laboratory. The variation in C-organic content between each sample's field was also shown in Table 3.7. Areca catechu produced the sample with the highest carbon content, which was only 4.08%.

Table 7. The result of C-Organic Test and Analysis on the Number of Organic Substance based on the Species in each Observation site

No	Species Names	Result of Code Sample Analysis	
		Water Content (%)	C-Organic (%)
1	*Swietenia mahagoni*	4.17	0.97
2	*Samanea saman*	3.09	1.36
3	*Sesbania sesban*	5.93	3.00
4	*Gmelina arborea*	6.38	3.65
5	*Leucaena leucocephala*	3.09	2.76
6	*Ailanthus altissima*	3.73	2.36
7	*Casuarina equisetifolia*	4.17	0.38
8	*Swietenia mahagoni*	4.38	1.50
9	*Pandanus tectorius*	4.38	1.34
10	*Areca catechu*	2.25	4.08

Table 7 provided insights into the physiological characteristics and potential carbon sequestration abilities of each species. Species with higher organic carbon content might play a more significant role in carbon sequestration, contributing to mitigate climate change. Areca catechu, Gmelina arborea, and Sesbania sesban show relatively higher organic carbon content, potentially indicating their importance in carbon capture. These findongs can guide conservation efforts, restoration projects, and land management strategies by considering the carbon sequestration potential of different species. Further research could explore how these traits interact with other environmental factors and contribute to overall ecosystem health, particularly in Limboto Lake Site. The total carbon stock in each field varied according to the types of soil, the management strategy, and the diversity and density of the existing plant species (Hairiah et al., 2010).

The difference in the state of the environment in which the plants are growing and the measurement method used by the researcher, according to Suwarna (2012), is what leads to different results and a smaller or closer look. The relationship between biomass and its habitat is stronger the smaller the biomass component. As a result, each location produced a different value for the stem's absorption of carbon due to the unique conditions of each species' growing environment. This distinction can be fundamentally seen in the state of the plant. A standing tree's biomass and carbon stock will be impacted along with its advancing age (Rohmatiah et al., 2017; Sitaniapessy & Papilaya, 2018).

CONCLUSION

The highest IVI for the vegetation in the Soekarno Landing Area was recorded at the sawlog level by *Swietenia mahagoni*, with a score of 82.86; at the sapling level by *Leucaena leucocephala*, with a score of 79.56%; and at the seedling level by *Manihot esculenta*, with a score of 46.33%. *Leucaena leucocephala*, *Leucaena leucocephala*, and *Nauclea orientalis* all had high IVI scores for the plants in the area of Limboto Lake, with a sawlog level value of 76.90%, 70.03%, and 53.06%, respectively. *Swietenia mahagoni* and *Samanea saman* attained the highest carbon content and CO_2 absorption in the two locations, while *Leucaena leucocephala* took the top spot at sapling level. The test results of C-Organic produced a higher average score when comparing the Limboto Lake area to the Soekarno Landing Area. *Areca catechu* produced the highest sample, with a C-Organic content of up to 4.08% .

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