Urban forest carbon stock and biodiversity assessment at Nagan Raya Regency

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Abstract. Urban forest at Nagan Raya Regency is located in the central government and becomes a green open space that provides many benefits both directly and indirectly for the entire community in the region. Nagan Raya urban forest has various types of trees that usually found in low land mineral soil, such as *Vitex pubescens* locally known as Mane and *Artocarpus blumei* locally known as Tarap. Besides, the urban forest of nagan raya has become the habitat of several species of primates, reptiles and birds. In order to calculate the carbon stock of Nagan Raya urban forest, we use the “carbon calculator” tool developed by Michigan State University. By using nested plot of 5 m x 5 m for pile (small tree) category; 10 m x 10 m plot for pole (medium tree) category and 20 m x 20 m plot for tree category. With 12 total plots that are systematically spread throughout Nagan Raya urban forest. Averagely, carbon stock at Nagan Raya urban forest is 353,72 tCha⁻¹. Naturally, trees in the climax condition tend to have less increment and will rotten. We suggest that maintenance and replanting of Nagan Raya urban forest is necessary to replace plants that have entered the category of "old" or low increment with made regeneration types to optimize the function of Nagan Raya urban forest as one of the buffer systems for the urban community.

1. Introduction

Urban forest is an open area and overgrown by various types of tree vegetation with a composition and structure resembling a forest and located in an urban area/residential environment. Urban forests are designated as part of Green OpenSpace (RTH) with various important functions, including: providing a beautiful and comfortable environment for city dwellers, as an open tourist spot, able to reduce the adverse effects of air pollution, reduce noise and have others ecological functions. Urban forest is an area of extensive woody vegetation, and its area is open to the public, easily accessible by city dwellers and can fulfill protective and regulatory functions, such as soil conservation, water management, climate amelioration, an antidote to air pollution, noise and others.

Along with the reduction in forest area due to degradation and deforestation, the role of urban forests as "miniature" forests in residential areas is increasingly felt to be important, especially in absorbing carbon (pollutants) produced by various urban community activities [1]. Environmental factors, especially altitude, has a big impact on plant growth. Because, the height factor affects the factor other related environment with a groth prosess (ex : climate, rainfall and temperature air) [2].
The government center of Nagan Raya Regency is surrounded by settlements, shop houses and office buildings with various public facilities and other social support. One of the public facilities that is quite representative is the availability of green open space which is one of the icons of the capital city of Nagan Raya Regency, namely the Nagan Raya Urban Forest. In the central spatial planning of the Nagan Raya City Government, the position of the urban forest is in the "center" of the Nagan Raya Government offices. Standing on state land, the city forest of Nagan Raya has an area of approximately 5 hectares.

As a natural ecosystem, Nagan Raya urban forest has a collection of various types of tree vegetation originating from various mineral soil tropical forest areas in the Nagan Raya Regency area. The purpose of this study was to determine the carbon reserves and biodiversity wealth stored and owned by the Nagan Raya urban forest.

2. Materials and methods

2.1. Creating plot sampling
Sample determination using the purposive sampling with random start to plot 1 and systematic to plot 12 nested plots in the 5-hectare area with 9,6% sampling intensity.

2.2. Carbon calculation
Data analysis is done by using several formulas, according to the formula used by [3]. The formula used in the calculation of tree biomass uses an allometric equation as follows:

\[
AGB = 0.125 \times D^{2.533}
\]

Where:
\( AGB \): Above ground tree biomass (kg/tree)
\( D \): Diameter at breast height (cm)

Calculation of the estimated stored carbon reserves according to the Intergovernmental Panel on Climate Change (IPCC) explains that 47% of biomass from forest vegetation is composed of carbon, so that stored carbon can be calculated using the following formula [4].

\[
C_{\text{carbon}} = AGB \times 4.7\%
\]

Where:
\( C \): Tree carbon (kg)
\( AGB \): Above ground tree biomass (kg/tree)
4.7\%: Constant

Carbon in forests can be used to calculate absorbed CO2 by forest vegetation by means of carbon biomass conversion factors. The total carbon weight obtained is multiplied by the carbon-CO2 conversion factor [5].

\[
CO_2 = Cn \times 3.67
\]

Where:
\( CO_2 \): Absorbed CO2 (ton/ha)
\( Cn \): Carbon content per unit area (ton/ha)
3.67: Equivalent number or C Conversion to CO2
(Atom C Mass = 12 and O = 16)
CO2->(1x12)+(2x16)=44
Conversion -> 44:12 = 3.67

From the calculation results above, information will be obtained on how much potential carbon reserve stock is in each type of tree in one area.

2.3. **Shannon-Wiener Index of Diversity**

Shannon-Wiener diversity index can be used to measure the diversity value [6]. Shannon Wiener index of diversity can be measured using the following formula:

\[
H' = -\sum p_i \ln (p_i)
\]  

Where:
- \(H'\) : Shannon-Wiener diversity index
- \(p_i\) : \(n_i / N\)
- \(n_i\) : Total of species-\(i\)
- \(N\) : Total of individuals from all species

The value index of diversity from Shannon-Wiener is 1-3, and can be categorized as follows:
- \(H' < 1\) : Low Diversity
- \(1 < H' < 3\) : Moderate Diversity
- \(H' > 3\) : High Diversity

2.4. **Margalef Index**

Species richness is total of species in certain area. Margalef suggest the species richness index combined with the value of abundance on each sample unit with the same size and placed in the same habitat or community. The calculation is called Margalef index and can be calculated using the following formula:

\[
DMg (Margalef) = \frac{S-1}{\ln N}
\]  

Where:
- \(N\) : Total of individuals from all species
- \(S\) : Total number of species
- \(\ln\) : Natural logarithm

The value index of species richness from Margalef can be categorized as follows [7]:
- \(DMg < 3.5\) : Low species richness
- \(3.5 < DMg < 5\) : Moderate species richness
- \(DMg > 5\) : High species richness

2.5. **Evenness Index**

Evenness index is calculated using the following formula [7]:

\[
E = \frac{H'}{\ln S}
\]  

Where:
- \(E\) : Pielou evenness index
- \(H'\) : Shannon-Wiener diversity index
- \(S\) : Total number of species

The value index of species evenness from Pieloi can be categorized as follows [8]:
- \(E < 0.3\) : Low species evenness
- \(0.3 < E < 0.6\) : Moderate species evenness
- \(E > 0.6\) : High Species evenness
3. Results and discussion

3.1. Carbon (tC/ha)
The total carbon stock in the urban forest area with an area of 5 ha is 353.72 tC. The data obtained in the calculation of carbon in the 12 plots, the plot that has the highest amount of carbon was plot 11 with a value of 120.85 tC/ha and the plot that has the amount of carbon with the lowest value was plot 9 with a value of 18.59 tC/ha. The impacts and threats that occur in this area include encroachment, forest fires, invasive animal or tree species, grazing areas, and the presence of garbage or waste. The average carbon stock in the Nagan Raya forest area is 70.74 tC/ha. There are seven plots that have carbon values above the average, namely plots 2, 5, 6, 7, 10, 11, and 12. 5 other plots below the average are plots 1, 3, 4, 8, and 9. The total number of trees counted was 150 stands, the highest density value owned by plot 2 with a value of 3,446.56 m³/ha, and the lowest density is plot 4 with a value of 151.63 m³/ha.

| No. | Plot ID | tC / Ha |
|-----|---------|---------|
| 1   | Plot 1  | 43.65   |
| 2   | Plot 2  | 102.24  |
| 3   | Plot 3  | 31.76   |
| 4   | Plot 4  | 53.58   |
| 5   | Plot 5  | 83.89   |
| 6   | Plot 6  | 71.99   |
| 7   | Plot 7  | 81.57   |
| 8   | Plot 8  | 65.00   |
| 9   | Plot 9  | 18.59   |
| 10  | Plot 10 | 104.94  |
| 11  | Plot 11 | 120.85  |
| 12  | Plot 12 | 70.86   |

| No. | Plot ID | tC / Ha |
|-----|---------|---------|
| 1   | Plot 1  | 1.714,18 |
| 2   | Plot 2  | 3.446,56 |
| 3   | Plot 3  | 1.136,02 |
| 4   | Plot 4  | 151,61  |
| 5   | Plot 5  | 301,81  |
| 6   | Plot 6  | 2.488,02 |
| 7   | Plot 7  | 3.218,43 |
| 8   | Plot 8  | 2.970,00 |
| 9   | Plot 9  | 1.002,54 |
| 10  | Plot 10 | 516,62  |
| 11  | Plot 11 | 577,53  |
| 12  | Plot 12 | 404,90  |
3.2. Evenness index
The evenness index value obtained for trees was 0.84 and for seedlings was 0.70. If the evenness value of a species was equal to 0 or < 0.3 then the value of the evenness of species was classified as low. If the value of the evenness of species was 0.3-0.6 then the value of the evenness of species was classified as moderate, and if the value of the evenness of species is > 0.6 then the level of evenness of species was high [9, 10]. With the evenness value of trees and seedlings of more than 0.6 it means that the level of evenness of species in the area was classified as high. Diversity index value, index species richness and species evenness index used to describe the situation environment based on biological conditions [10].

3.3. Margalef’s index
The value of the Margalef’s index at the tree level is 6.32 and the seedling level was 1.85. If the value of species richness is < 2.5 then the species richness in the area is classified as low, if the value of species richness from 2.5 - 4 means that the species richness was moderate, and if the value of species richness is > 4, it means that the area has high species richness [11]. At the tree level with a value of 6.32 means that the area has a high and diverse level of species richness. Index value was a category low, then the species richness index was also will be low. This is because species diversity was directly proportional with the value [12].

3.4. Shannon-Wiener diversity index
The Shannon-Wiener diversity index value at the tree level was 2.95 and at the seedling level was 73. If the value of diversity is < 1, the level of diversity was low, if the value of diversity was between 1 – 3, the level of diversity is moderate, and if the value of diversity was more than 3, the level of diversity was high [9] At the tree and seedling level with a diversity value of 2.95 and 1.73 is classified as a moderate level of diversity.

| Table 3. Biodiversity value. |
|--------------------------------|
| Trees > 5 cm Diameter at Breast Height (DBH) | Seedlings | Others Vegetation |
| Species Richness | 33 | 12 |              |
| Menhinick's Index | 2.63 | 0.61 |    |
| Margalef’s Index | 6.32 | 1.85 |    |
| Shannon-Wiener Diversity Index | 2.95 | 1.73 |    |
| Simpson Diversity Index | 0.93 | 0.78 |    |
| Evenness | 0.84 | 0.70 |    |
| 5 Most Abundantly species (Total of individuals) | Mane | Jambu jambuan | Tarap tarap tampang tampang |
| Tarap panah/tampang wangi | Mane | Jambu jambuan | Tarap tarap |
| Brangkah | Buah Lo hijau | Tabalik angin | Quadrant/Tree’s Plot (20 x 20 m) |
| Merbau | Tabalik angin | Quadrant/Seedling’s Plot (2 x 2 m) |
| Species | Total |
| Tree’s Plot | Liana/vines | 47 |
| Trees | Bushes | 598 |
| Seedling’s Plot | fern | 234 |
| Bushes | Pandanus | 11 |
| Others Vegetation | Little Bushes | 878 |
| Others herbal plantation | | |
| Accumulation | Quadrant/Tree’s Plot (20 x 20 m) | 12 |
| Quadrant/Seedling’s Plot (2 x 2 m) | 12 |
Species that are abundant seen from the total individuals at the tree level are locally known as mane, tarok panah/tampang wangi, tarap, brangkah, and merbau. The species that are abundant at the seedling level are guava, tarap, mane, buah lo hijau (*Ficus sp.*), and tabalik angin. In the urban forest area of Nagan Raya there are one protected species; protected here means rare species, it was merbau. Further identification must be carried out regarding the variety of plant species in the urban forest of Nagan Raya. In addition, it also conducts nurseries aimed at regenerating existing species to improve the condition of unfavourable forest areas. Plants that have a high tolerance will be the level existence to other types [13].

To increase the amount of carbon value in the forest area, what needs was to raise the seedlings and carry out maintenance and supervision to grow well. We must continue to plant to repair forest areas that have been damaged by encroachment, forest fires, land conversion and other problems. This area has a high species richness, so what must be done to maintain this species richness is to carry out periodic surveillance and create nurseries aimed at species regeneration. Species that have a dominant value in a community will have a high INP value [14, 15]. Ecologically with the diversity index and evenness index has a high value [16, 17].

4. Conclusions
The total carbon stock in the Nagan Raya urban forest area with an area of 5 ha is 353.72 tC from the 12 plots. The plot that has the highest amount of carbon is plot number 11 with the value of 120.85 tC/ha. The value of the richness with margalef index at the tree level was 6.32, so the Nagan Raya urban forest has a relatively high species richness. Meanwhile, from the index of evenness value obtained for trees was 0.84 and for seedlings was 0.70. This means that the Nagan Raya urban forest has a relatively good species evenness value.

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