Distribution and soil carbon stocks of agroforestry vegetation on dry land in Aceh Besar regency

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Abstract. Research to find out how big the potential of soil carbon in agroforestry vegetation in Aceh Besar regency. This research was conducted on agroforestry vegetation on dry land in the Aceh Besar regency. Content carbon on the type of agroforestry land-use, two samples were taken each composite soil on depth 0-5 cm, 5-10 cm, 10-20 cm, 20-30 cm, 30-70 cm and 70-100.

For the analysis of carbon content, activities are carried out in the soil laboratory and plants of the Faculty of Agriculture, Syiah Kuala University. The carbon content in agroforestry vegetation is quite high, and this can be described in the percentage of carbon which has a classification from high to very low. Soil depth 0-5 cm has a carbon percentage with a high classification value of 3.40 and at a depth of 30-70 cm has the lowest % C value of 0.35% with a very low classification. tends to increase soil C and N through increased root complementarity, lower underground competition.

1. Introduction

Soil is a very significant carbon storage container. The land will experience changes up to a specific period. Each layer of soil carbon is very influential on life and ecosystems. Carbon in the soil is critical to support life, human health, and support other ecosystem functions. Soil carbon can be interpreted as the primary source of life, being the basis of life, energy, food, and shelter [1]. Utilization of land for agricultural activities and produce biomass, food resources, feed, clothing, shelter, and bio-energy to support the life of living things [2]. Soil is a natural part that is directly related to the atmosphere layer. Earth's atmosphere contains nitrogen, oxygen, carbon dioxide, water vapor, and other gases. Through the pore space, the soil can drain and release gases into the atmosphere. With information on climate change, CO₂ gas emissions from the soil are significant because they affect greenhouse gases in the atmosphere [3].
Soil organic carbon plays a significant role in conserving soil, balanced ecosystems, and increasing soil fertility and crop productivity [4]. Soil carbon sequestration on agricultural land has a significant role in mitigating climate change, provided that specific changes in soil management are implemented [5]. Approximately 45% of the world’s land is used for agriculture [6]. For this reason, changes in soil organic carbon content can have a significant effect on climate change mitigation.

According to [7], conversion of agricultural land to plantation forest can increase soil organic carbon stock by 29%. Reforestation is a common land-use change strategy that substantially increases cycle C and increases soil C stocks [7]. In Europe, the average soil organic carbon stock is assumed to increase by 21 ± 13 Mg ha\(^{-1}\) after afforestation [8]. In general, increasing soil organic carbon stocks through reforestation is beneficial to overcoming greenhouse gas emissions that contribute to global warming and increase soil fertility and productivity [9-10]. A significant increase in soil carbon stocks for 30 years after reforestation can increase soil organic carbon stocks, which are only obtained in agroforestry land-use types [11].

Plantations using agroforestry systems, using systems of two or more different plant species, can result in higher biomass production and litter collection, and it is seen that the utilization of soil resources is more efficient than single-crop systems [12]. The results of previous studies have shown that a mixture of two or more plant species (trees, shrubs, or herbs) can increase soil C and N storage through mutualism (the existence of one species supports the other by assisting growth conditions) and optimal soil utilization of single plant species resources. [13-14]. However, mixed plant species (agroforestry) in an ecosystem greatly influences changes in crop patterns, soils [15], and different ecosystems, either differing in their nutrient storage capacity based on the comparison of different plant species or the dominant influence of plant species [16].

The results of this study are a continuation of research [17] which divides the soil depth at levels: 0-15, 15-30, 30-45, and 45-60 cm for the study of soil organic carbon sequestration [17]. At the same time, this research was carried out at soil depths at levels: 0-5, 5-10, 10-20, 20-30, 30-70, and 70-100 cm. In general, mixed garden vegetation (agroforestry) is one of the main components in the contribution of dry land in Aceh Besar regency and forest vegetation, dryland agriculture, and open land. Soil carbon availability in agroforestry vegetation needs to be researched to maintain sustainable agricultural cultivation and environmental conservation actions of land resources as optimally as possible. For this reason, to assess the potential of soil carbon in agroforestry vegetation and future treatments that will be carried out, both reforestation and soil management to increase soil carbon stocks for the future. In this case, it is necessary to conduct a research study to determine how much soil carbon potential is in agroforestry vegetation in the Aceh Besar regency.

2. Methodology
This research was conducted on dryland agroforestry vegetation in Aceh Besar regency. In addition to the field, the analysis was also carried out at the Soil and Plant Research Laboratory, Fakultas Pertanian, Universitas Syiah Kuala. Soil samples were taken at each point, and two soil samples were taken at a depth of 0-5 cm, 5-10 cm, 10-20 cm, 20-30 cm, 30-70 cm, and 70-100 cm, then analyzed for soil carbon carried out in the laboratory.

Soil organic carbon analysis was carried out using the Walkley and Black method based on the provisions of the BPT analysis guidelines by reacting 0.5 g of fine soil sample (<0.5 mm) with 5 ml of \(\text{K}_2\text{Cr}_2\text{O}_7\) solution and 10 ml of \(\text{H}_2\text{SO}_4\) on a hotplate. After cooling, 5 ml of \(\text{H}_3\text{PO}_4\) and 50 ml of distilled water were added and allowed to stand for some time. Then it is titrated with 0.025 M FeSO\(_4\) solution using a burette to turn a clear green color and writes down the volume of FeSO\(_4\) solution used in the sample with the blank (without soil). Soil C-Organic value criteria can be categorized: very low (<1.00), low (1.00-2.00), moderate (2.00-3.00), high (3.00-5.00), and very high (>5.00) [18].

The amount of carbon contained in the soil is by multiplying several experimental parameters. Calculation of soil carbon density is carried out using the following formula [19]:

\[
C_t = K_d \times \rho \times \% \text{ C organic}
\]  \hspace{1cm} (2.1)
Information:

\[ C_t \] = soil carbon content, expressed in grams (g cm\(^{-2}\))
\[ K_d \] = depth of soil sample, expressed in centimeters (cm)
\[ P \] = Bulk Density (bulk density), expressed in grams per centimeter cubic (g cm\(^{-3}\))
\[ \% C \text{ organic} \] = the value of \% carbon content is 0.47 or using the percent value of carbon obtained from the results of measurements in the laboratory.

Data from field measurements and laboratory analysis are presented in the form of C distribution in the soil, then converted to area estates (hectare). The carbon stock in the soil is converted to each area and expressed in tons ha\(^{-1}\), which is then processed statistically using descriptive statistical methods to compare the existing carbon stock and content.

3. Results and discussion

Table 1. Bulk density, soil carbon content, and carbon potential in agroforestry land-use types in Aceh Besar regency.

| Depth (cm) | Agroforestry | BD (g cm\(^{-1}\)) | % C | Potential C (ton ha\(^{-1}\)) |
|------------|--------------|--------------------|-----|-----------------------------|
| 0-5        |              | 1.28               | 3.40| 21.76                       |
| 5-10       |              | 1.28               | 2.57| 16.44                       |
| 10-20      |              | 1.28               | 1.34| 17.15                       |
| 20-30      |              | 1.48               | 0.70| 10.36                       |
| 30-70      |              | 1.48               | 0.35| 20.72                       |
| 70-100     |              | 1.48               | 0.98| 43.51                       |
| **Average** |              | **1.38**           | **1.56** | **129.94**         |

*Source: Laboratory analysis results*

Table 1 above shows that the C content in agroforestry land use has a reasonably high value. It is from the \% C, which has criteria from high to very low. Soil depth 0-5 cm has \% C, which has high criteria, namely with a value of 3.40, and at a depth of 30-70 cm has the lowest \% C value, which is 0.35\% with shallow criteria.

The results of field observations indicate that the use of agroforestry land has one characteristic. Namely, the soil is thought to be quite fertile. In the agroforestry area, much litter falls to the soil surface and accumulates, thus affecting the \% C of the soil itself. When observed in the field, the type of agroforestry land use has a clay texture on the topsoil and a sandy clay texture on the subsoil. It can be seen from the \% C obtained at 0-20 cm depth with low, medium, and high criteria. The sub-soil in this mixed garden area has a more dominant clay and sand texture, and the \% C obtained has shallow criteria.

The study [20] found that the use of agroforestry land has a C reserve of 160.4 tons ha\(^{-1}\), which is higher than the research results obtained in The Aceh Besar regency. It occurs because the use of agroforestry land in the observed Aceh Besar regency has a less dense plant density, so that the amount of litter produced is minor and makes the soil C content lower [20].
Figure 1. Distribution and area of soil carbon vegetation agroforestry in Aceh Besar regency.

Based on figure 1 above, it can be seen that the area of dry land agroforestry in Aceh Besar regency is 15,052.09 ha of the total dry land in Aceh Besar district of 239,387.91 ha. Therefore, it is necessary to plant woody plants to increase soil carbon and reduce the area of dry land use in other vegetation. Conservation tillage such as applying mulch and organic fertilizers can increase soil carbon and reduce other dryland vegetation in the Aceh Besar regency. The vegetation found in the dry land-use type of agroforestry in Aceh Besar regency is *Alstonia villosa*, *Acacia mangium*, *Tectona grandis*, *Areca catechu*, *Syzygium aromatium*, *Aluerites moluccanus*, *Murraya koenigi*, *Cocos nucifera*, *Mangifera indica*, *Gnetum gnemon*, *Syzygium aromatium*, *Lannea coromandelica*, *Artocarpus heterophyllus*, *Averrhoa bilimbi*, and *Nephelium lappaceum*.

Table 2. Soil carbon stocks in dryland agroforestry vegetation in Aceh Besar regency.

| Land utility type | Carbon potential (ton ha\(^{-1}\)) | Area (ha) | Carbon stock (tons) |
|------------------|-----------------------------------|----------|-------------------|
| Agroforestry     | 129.94                            | 15,052.09| 1,955,868.57      |

It can be seen in table 2 above that soil carbon stock in dry land-use type agroforestry is 1,955,868.57 tons. The variety of plants and the number of woody plants can affect soil organic carbon and increase soil fertility. It follows the research results of [21], which states the importance of plant species and diversity in studying the dynamics of above-soil nutrients in agroforestry systems. The ratio of soil organic carbon in agroforestry plants (trees and shrubs) is higher than that of single plant species (trees or shrubs only) [21].

The results showed that the vertical distribution of soil organic carbon at soil depths (0–10 and 10–20 cm) indicated that soil organic carbon would decrease with increasing soil depth in bush and tree shrub yards. High plant diversity can increase soil C and N values by increasing root complementarity, reducing underground competition [22-24].

4. Conclusion

The carbon content in agroforestry vegetation is relatively high. This can be described in the percentage of carbon which has a classification from high to very low. Soil depth 0-5 cm has a carbon percentage with a high classification with a value of 3.40 and at a depth of 30-70 cm has the lowest % C value of 0.35% with a very low classification. tends to increase soil C and N through increased root complementarity, lower underground competition
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