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Analysis Distribution of Biomass Carbon of Grasslands, Shrubs, and Rainfed Rice Fields on Dry Land in the Aceh Besar District Indonesia

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Abstract
This research was conducted to determine plant biomass, carbon potential, and CO_2 reserve potential in understory vegetation in general, namely grasslands, shrubs, and rainfed rice fields. The sampling of the research was carried out randomly and intentionally, and was limited to the vegetation of reeds, shrubs and rainfed land bushes in the Aceh Besar District of Indonesia. The sample was taken based on a digitized map obtained from overlaying the land use map, slope map, soil type map, and Aceh Besar government map. Measurement of biomass in the vegetation of Imperata, shrubs, and rainfed rice fields is in accordance with procedures from the Indonesian National Standard (2011) and the World Agroforestry Center. The area of bush vegetation is larger than that of rainfed rice fields and grasslands. In general, the plants found in bush vegetation are *Acacia leucoeplhoea*, *Mimosa pudica*, *Cyperus rotundus,* and *Eleusine indica*. Grassland vegetation has one plant only, namely, *Pennisetum purpureum*. The vegetation of rainfed rice fields consists of the *Oryza sativa* type of plant. Plant biomass, carbon [C] content, and carbon potential in bush vegetation are greater than that of grassland and rainfed rice fields, as well as plant biomass reserves, plant biomass carbon and total CO_2 reserves. Shrubs and woody plants render the potential for biomass, carbon, and CO_2 absorption greater than that of grassland and rainfed rice fields. This is in accordance with the research that the increase in biomass is followed by an increase in potential carbon storage. Parameters that affect biomass indirectly will also affect carbon storage in a biomass and in an ecosystem, namely, individual density, stem diameter, tree species diversity, and soil. The density of trees in an area will affect the increase in carbon stocks through an increase in biomass. This is because the vegetation of shrubs does not only consist of undergrowth, but also of woody stems such as *Acacia leucoeploea,* making carbon stock potential in bush vegetation greater than that of grassland and rainfed rice fields, as shrubs cover an area of 96,962.2 ha, hence larger than that of grasslands and rainfed rice fields.

1. INTRODUCTION

Biomass determines the effective amount of carbon that can be released into the atmosphere in the form of CO_2 when trees in a forest are chopped, clear-felled, or burned. In principle, plants with high biomass do not always mean that these plants are better than other plants in absorbing carbon. Other factors also play an important role, such as plant age, soil fertility, and type of cultivation. Therefore, the measurement of plant biomass utilizes units of mass per unit time per unit area, for example kg/ha/year, to be able to assess and compare the capabilities of each plant [Yusuf et al. 2014].

Changes in temperature, light, nitrogen, and land use also affect the biomass and composition of the herbaceous layer in vegetation [Baeten et al. 2010; Verheyen et al. 2012; Perring et al. 2017]. Several previous studies have shown that climate change, increased amount of light, and nitrogen enrichment, alone or in combination, can generally increase understory biomass, which is highly correlated with plant cover [Bonan 2008; Maes et al. 2014]. The estimation of understory biomass under dynamic growing conditions can provide very important information in decision-making while monitoring the condition of bush vegetation. Several components should

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be considered when monitoring shrub biomass, including total biomass, aboveground biomass, stem biomass, foliage biomass, and root biomass. Each component has a unique and important function [González- González et al. 2017].

Dry land is defined as a land area that experiences a drought index (i.e., the ratio of the average annual rainfall to the average annual potential evapotranspiration) of less than 0.65, representing the major ecosystems in tropical and temperate regions among all continents [Pravalie 2016]. Limited biomass productivity, lack of groundwater, form, and other unique soil physicochemical properties have contributed to the relatively low soil organic carbon content of dry land [Weil, Brady 2017] where soil degradation occurs. The loss of soil organic C and C emissions from degraded dry land can be reduced by carrying out restoration actions that can improve soil quality, soil organic carbon content, and biomass productivity [Arshad et al. 2016].

Dry land denotes a specific condition that threatens ecosystems and human well-being. Increased human intervention has worked well to reduce vulnerability that appears to be important in inhomogeneous dry land conditions. On dry land, it quantitatively shows the most important dimensions including poverty, water stress, soil degradation, agro-natural constraints, and isolation. The development of dry land vulnerability depends on how well human livelihoods are adapted to the typical agro-natural constraints of dry lands [Sietz et al. 2011].

Dry land covers the most geographically, biologically least productive, and fastest growing demographic of the earth. Livelihoods in these semi-arid and arid regions have developed under varied, unpredictable environments and under extreme conditions [Huber-Sannwald et al. 2012]. Land use affects dry land use patterns in the form of land cover modification, with changes occurring slowly and gradually within one land cover class [Lambin et al. 2006].

Carbon sequestration can be defined as the process of capturing and removing CO_2 in the atmosphere and other forms in the long term to reduce and delay global warming. This can be done through biological, chemical, and physical methods or mechanisms including artificial mechanisms. This process involves the production of biomass by capturing CO_2 with several photosynthetic mechanisms to produce energy [Eloka-Eboka, Inambao 2017]. Atkin et al. (2012) and colleagues noted in their research that the sequestration action only depends on the carbon sequestration properties achieved through several methods and forms. Storing CO_2 and other forms of carbon can indeed help reduce the effects of greenhouse gases.

This research acts as the basis for previous research conducted by Hao Xu et al. (2020), which states that accurate estimation of understory biomass is very important in natural resource management. The condition of the area of vegetation is an important factor that affects the dynamics of understory biomass. The difference is in the research of Hao Xu et al. conducted in areas with high-intensity rainfall. However, this research was conducted in the Aceh Besar District with low rainfall in dry land areas. This research was conducted to determine plant biomass, carbon potential, and potential CO_2 reserves in understory vegetation in general, namely grasslands, shrubs, and rainfed rice fields. The purposes of this study are to determine the potential and carbon reserves of plant biomass in grassland, shrubland, and rainfed rice field and to determine the potential for CO_2 uptake and reserves on these areas. The novelty in this study is to examine plant biomass carbon and CO_2 absorption potential in shrubland, grassland, and rainfed rice fields and then compare them.

2. RESEARCH MATERIALS AND METHODS

Materials and equipment used for measurements and observations in the field include a map of research locations, a global positioning system (GPS), digital altimeter, tape measure, callipers, clinometer, sample bag, and camera. Meanwhile, the laboratory equipment includes digital scales, oven, chamber furnace, and burette.

The sample was taken based on a digitized map obtained from overlaying a land use map, slope map, soil type map, and an Aceh Besar District administrative map. The biomass in this study refers to all living organic matter in the form of litter, living plants, and wood or twigs that are on the soil surface or under soil [Kebede, Soromessa 2018]. However, the biomass carbon measured in this study was above-ground biomass the location of which was chosen purposely to represent each land use type. The field observation technique was to estimate the volume and distribution of carbon biomass from various vegetation groups using the procedure proposed by Sutaryo (2009). The overall measurement method used is the allometric method adjusted to the type of vegetation/trees or stands and parts of plants/trees.

The researcher carried out this method for developing allometric formulas, especially for tree species that have a distinctive branch growth pattern for which allometric equations have not been obtained globally. Allometric development is done by measuring the diameter, length, and mass weight. The method can be carried out on understory plants, annual plants, and shrubs. The measurement of biomass of reeds, shrubs, and rainfed rice fields is in accordance with the Indonesia National Standard rules (2011) and the World Agroforestry Centre [Hairiah, Rahayu 2007].

It is necessary to make plots according to field conditions to determine each vegetation growth on the seedling plot size with a minimum area of four m2 (growth rate of wooded vegetation < 2 cm in diameter with a height of 1.5 m). Afterwards, it is essential to stake plots with a minimum area of 25 m2 (growth rate of wooded vegetation with a diameter of 2 cm to < 10 cm). Both seedling and sapling plots was repeated 5 times.

The total dry weight of understory/litter per quadrant was calculated using the following formula:

$$\text{Total BK (g) =}$$
$$\text{(Sub sample BK (g)/Sub - Sample BB (g)) * Total BB (g)}$$

Table 1. Estimation of tree biomass using allometric equations

No.	Type/group of trees	Estimated Tree Biomass (kg/tree)	Reference source
1	Branched tree	$BK = 0.11 * \rho * D^{2.62}$	Ketterings (2001)
2	Unbranched tree	$BK = \pi * \rho * H * D^2/40$	Hairiah et al. (1999)
3	Pruned coffee tree	$BK = 0.281 * D^{2.06}$	Arifin (2001)
4	Banana	$BK = 0.030 * D^{2.13}$	Arifin (2001)
5	Bamboo	$BK = 0.131 * D^{2.28}$	Priyadarsini (1999)
6	Chinese Albizia	$BK = 0.0272 * D^{2.831}$	Sugiharto (2002)
7	Pine	$BK = 0.0417 * D^{2.6576}$	Waterloo (1995)

Where D is plant stem diameter
Source: taken from research

Where BK = dry weight and BW = wet weight, sub-sample is part of the plant biomass [Hairiah et al. 2011].
The stages of tree biomass measurement are as follows: identification of tree species names; measuring the diameter at breast height (dbh); record dbh data and type names into tally sheet; and calculate tree biomass [Indonesia National Standard 2011]. Then the tree biomass will be mixed with the leaf biomass (determined dry weight) and roots.
Calculate the volume and bulk density of wood with the following formula:

$$\text{Volume } (cm^3) = \pi * R^{2} * T$$

Where R is radius and T is height.
SG (specific gravity) wood can be calculated with the formula:

$$SG\ (gr / cm^3) = \text{Dry Weight } (g)/\text{Volume } (cm^3)$$

The estimate of tree root biomass can be done using the installed value, which is based on the crown and root ratio values. Estimated general ratio between canopy biomass and root share for wet tropical forest on dry land is 4:1 [Mokany et al. 2006]. Wetlands and trees in poor soils have the ratio at 10:1 [Ramankutty et al. 2007].
The calculation of carbon from biomass uses the following formula:

$$Cb = B * \%\ C\ organic$$

Where Cb is the carbon content of biomass, expressed in kilograms (kg); B is the total biomass, expressed in (kg); % C is organic is the percentage value of carbon content, amounting to 0.47 or using value percent of carbon obtained from the calculations in the laboratory.
The potential for CO_2 absorption in plants per hectare can be formulated as follows:

$$WCO_2 = Wtc * 3.67$$

Where Wtc is the carbon content of each plant stand and 3.67 is the equivalent value of the element Carbon C to CO_2 [Makundi et al. 1997; Murdiyarso 1999].

3. RESULTS AND DISCUSSION

Figure 1 shows that the area of grassland vegetation is 80.50 ha, the area of shrubs is 96,962.2 ha and the area of rainfed rice fields is 4,478.57 ha from the total dry land area in Aceh Besar District at 239,439.63 ha.
Figure 1 shows that the area of bush vegetation is larger than that of rainfed rice fields and grasslands. In general, plants found as shrubs are *Acacia leucoeplhoea*, *Mimosa pudica, Cyperus rotundus* and *Eleusine indica*. A grassland vegetation plant is *Pennisetum purpureum,* and *Oryza sativa* is found in rainfed rice field vegetation. According to Abdullah et al. (2022), grassland areas are predominantly covered with low layer vegetation such as *Imperata cylindrica, Cyperus rotundus*, *Paspalum conjugatum, Paspalum commersonii*, *Bidens pilosa, Panicum repens, Cyathula prostata, Axonopus compressus, Euleusine indica, Physalis angulata, Abrus precatorius, Borreria laevis, Hedyotis diffusa, Portulaca grandiflora,* and *Pennisetum purpureum*.
Tables 2, 3, and 4 show that the potential of plant biomass, plant biomass carbon, and CO_2 absorption is greater in shrub vegetation than in grassland and rainfed rice fields. Similarly, the reserves of all of them are found much more in vegetation of shrubs than grassland and rainfed rice fields because the shrub land contains undergrowth and wooded plants. This is in accordance with the research of Istomo and Farida (2017) stating that the increase in biomass goes hand in hand with the increase in the quantity of carbon storage potential. Ridwanullah (2011) also reinforces the finding that the huge potential of carbon converted by biomass greatly affects the size of the tree diameter. Forest stand density and the quantity of trees are one of the determining factors for massive carbon storage in this type of land use. The density of the stand also indicates the quality of the place for growth. The results of the research by Yuniawati et al. (2011) stating that the dominant amount of carbon in the stems is due to its wood component, and wood is made up of element carbon and extractive substances, hemicellulose, cellulose, and lignin.
Table 2 shows the potential carbon in grassland vegetation at 15.1 ton.ha-1, shrubs at 24.50 ton.ha-1 and rainfed rice

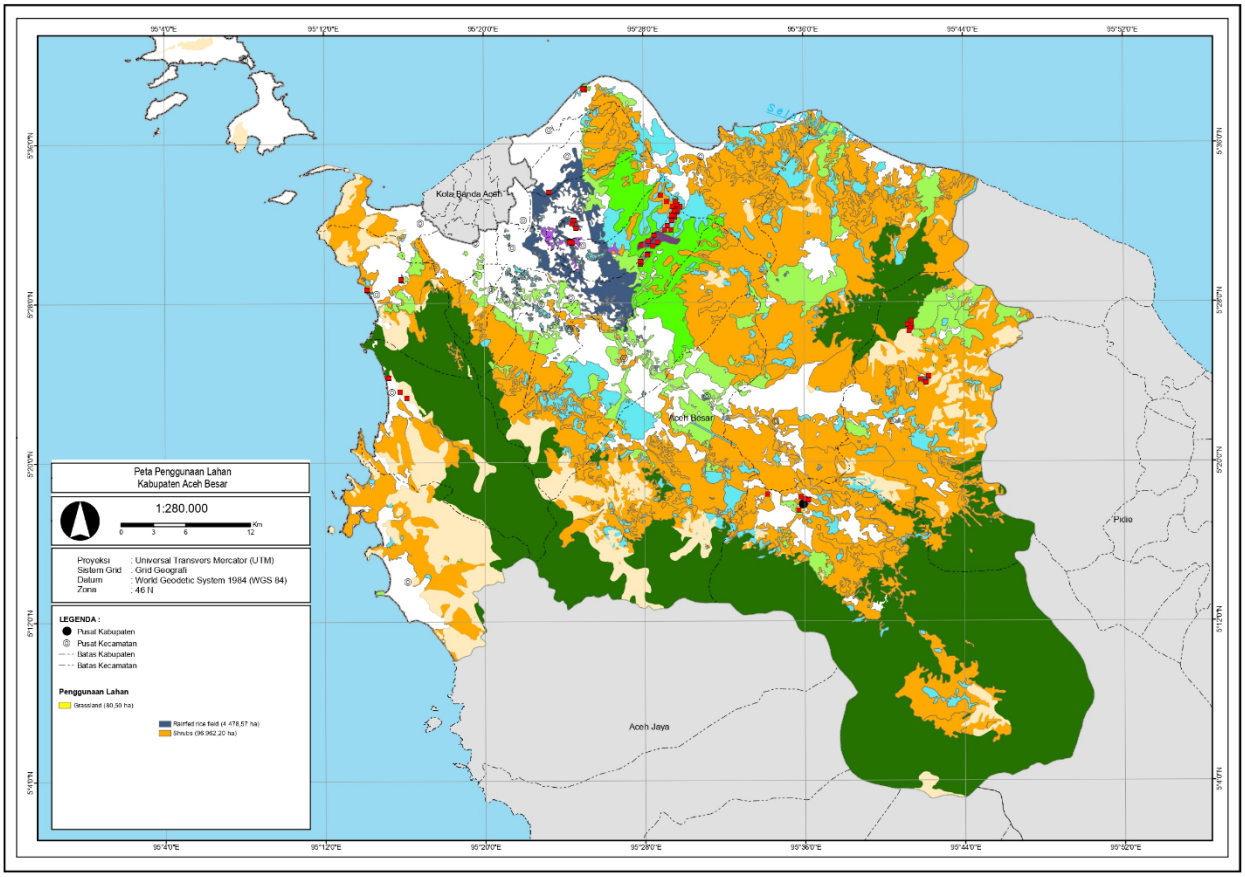


Figure 1. Map of the distribution and area of grasslands, shrubs, and rainfed rice fields on dry land in the Aceh Besar District

Table 2. Potential and total biomass of grasslands, shrubs, and rainfed rice fields on dry land in the Aceh Besar District

No.	Land Utility Type	Potential Biomass (ton ha^{-1})	Area (ha)	Total Biomass (Gg/LUT)
1.	**Grassland**	29.71	80.50	2.39
2.	**Shrubs**	48.21	96,962.2	4,674.39
3.	**Rainfed Rice Field**	9.38	4,487.57	42.02

Table 3. Biomass carbon and total carbon potential of grasslands, shrubs and rainfed rice fields on dry land in the Aceh Besar District

No.	Land Utility Type	Carbon Potential (ton.ha^{-1})	Area (ha)	Total Carbon (Gg/LUT)
1.	**Grassland**	15.1571	80.50	1.22
2.	**Shrubs**	24.50	96,962.2	2,375.37
3.	**Rainfed Rice Field**	4.79	4,487.57	21.43

Table 4. Potential carbon dioxide absorption on grasslands, shrubs, and rainfed rice fields on dry land in the Aceh Besar District

No.	Land Utility Type	CO_2 absorption potential (ton.ha^{-1})	Area (ha)	Total CO_2 absorption (Gg/LUT)
1.	**Grassland**	109.03	80.50	8,876.14
2.	**Shrubs**	176.92	96,962.2	17,154.55
3.	**Rainfed Rice Fields**	34.44	4,478.57	154.44

field at 4.79 ton.ha-1. Rochmayanto et al. (2014) stated that the standard of carbon stock in biomass for shrubs is at 10.51 tons.ha-1 and for grassland and rainfed rice fields at 1.47-3.57 ton.ha-1.

Ma and Wang (2020) stated that the age of the *Reaumuria Soongorica* bush had a significant effect on the allometric measurement of the bush and biomass reserves. The main biomass reserves in rough branches and roots are the largest proportion of the total biomass when bush plants become mature. Meanwhile, the proportion of fine roots and leaves decreases relatively with the age of the bush plants. Almost all components of shrub biomass showed a significant correlation with stem diameter. The dominance of non-uniform vegetation on shrubby vegetation consisting of woody plants and understory plants has greater biomass than uniform vegetation on grasses.

The tables above show that shrubs have an area of 96,962.2 ha as opposed to grasslands and rainfed rice fields. This means that the larger an area of vegetation, the higher the increase in CO_2 storage in the aboveground biomass.

4. CONCLUSION

The potential for plant biomass, plant biomass carbon, and CO_2 uptake is greater in shrub vegetation than in grassland and rainfed rice fields as well as in their reserves. As the land contains a great deal of shrubs and woody plants, it has greater potential for biomass, carbon, and CO_2 absorption than the others do. Therefore, the increase in biomass goes hand in hand with the increase in carbon storage potential. Parameters that affect biomass indirectly will also affect carbon storage in a biomass and in an ecosystem, ranging from individual density, stem diameter, tree species diversity, and soil. The density of trees in an area will affect the increase in carbon stocks through the biomass increase. With an area of 96,962.2 ha, shrub vegetation has greater potential for total carbon than that of grassland and rainfed rice fields. The larger a vegetation area, the likelier the CO_2 storage in the above ground biomass can increase.

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