The capacity of *Anacardium occidentale* L. to the environment: ability to C-stock and reduction of CO₂ gas emissions (case study in Pondok Village, Ngadirojo, Wonogiri)

B Pujiasmanto¹, E S Rahayu², E Murniyanto³*

¹Agroecotekhnology Departement, Agriculture Faculty, Sebelas Maret University, Surakarta, Indonesia
²Agribussines Departement, Agriculture Faculty, Sebelas Maret University, Surakarta, Indonesia
³Agroecotekhnology Departement, Natural Resouces Management, Agriculture Faculty, Trunojoyo University of Madura, Indonesia

*Corresponding author: ekomurniyanto@trunojoyo.ac.id

Abstract. Cashew plants are generally evergreen, so they cover land throughout the year, have a dome-like canopy shape and thick leaves are thought to reduce CO₂ emissions, one of the gases that triggered global warming that likely turned into climate change. The research aims to measure carbon stocks and reduce CO₂ gas emissions in cashew nuts has been carried out in Pondok Village, Wonogiri, Central Java, one of the cashews growing centers in Indonesia. The method of determining plant samples was carried out on cashew crops by monoculture, the age groups (KU) were differentiated 1, 2, 3, 4 and 5, the measuring plots were determined purposively due to the limited population in the same age plot. Carbon stocks were analyzed using the allomeric method, while CO₂ emissions were calculated descriptively. The results showed that cashew plants have the ability to increase carbon stocks and reduce CO₂ gas emissions, this ability is quadratic in line with plant KU. The highest carbon stock by KU 4 plants, the highest ability to reduce CO₂ emissions is found in plants aged 30-40 years. The implications of research results on crop management related to emission reduction and increase in C-stock are discussed.

1. Introduction

Plants are composed of elements (CHO)n, through the mechanisms of photosynthesis and respiration to form biomass [1]. Forest trees function as a storage area for carbon, the amount depends on the part being measured, the stage of growth, the level (strata) of plants and environmental conditions [2]. Referring to this definition, plants have the same function, individually their abilities depend on morphological characters, growth rates and periods of growth.

The cashew plant lives all year round, has sympodial branches, is shaped like an umbrella or dome to the ground surface, the leaves are oval-shaped, relatively thick, arranged at the end of the branch, fingers, flat. Between the branches close together, the leaves fill the empty space, forming a dense canopy. The rate of plant growth depends on the variety, age and growing environment. The plant growth period is included in the category of perennial crops, it does not shed leaves, but there is a bearing perennial period. The optimum growing environment for cashew plants is at an elevation of 200-400 m above sea level (masl), growing on dry land such as Ultisols, Alfisols, Oxisols and their associations as well as from lime as parent material.
The growth and development of plants depends on the processes of photosynthesis and respiration carried out, when the rate of photosynthesis is high (source), the plant growth rate is fast, in turn large deposits (sinks), the faster the biomass is formed. In line with age and growth of plant morphological components, the role of certain organs decreases. For example, if there is over shading, the closed leaves can be negative, the plant makes an effort to shed the leaves through stimulation of the hormonal system, as well as on twigs and branches. In connection with the carbon issue, plants have an important role because of their ability to absorb CO\(_2\) and then convert it into carbon, although plants also contribute to CO\(_2\) emissions through the performance of respiration at night and the process of decomposition of dead biomass. The activity of microorganisms in decomposing biomass produces CO\(_2\) into the atmosphere [3]. The flow of carbon from the atmosphere to vegetation is a two-way flow, namely the binding of CO\(_2\) to the biomass through photosynthesis and the release of CO\(_2\) into the atmosphere through the process of decomposition and combustion [4]. Measuring the amount of carbon in biomass in a land can describe the amount of CO\(_2\) in the atmosphere that is absorbed by plants [5]. The absolute carbon content in biomass at a certain time is known as carbon stock [6]. The process of carbon storage in the body of living plants is known as sequestration (C-sequestration) [7].

Plant biomass measurement can be done by measuring the dry weight of the biomass, but this is not easy to do on large trees or vegetation, therefore some researchers use allometric equations [8]. Measure vegetation biomass in the field with changes [9]. Field biomass components measured include crown thickness, canopy density, percentage of canopy cover and percentage of lower vegetation cover. Based on the assumption used, namely that the biomass standard intended for upper vegetation is equivalent to the biomass of vegetation/understorey. Plant and understorey biomass was measured by placing quadrants on the land under the trees, each side measuring 0.5 x 0.5 m, then harvesting trees Ø < 5 cm, herbs and grasses, weighing wet weight (BB), dry in the oven at temperature 80°C for 48 hours, weigh dry weight (BK).

Plant biomass was calculated using the allometric equation used by [11] namely:

\[
\text{Dry Weight Trees Biomass} = 0.112 \times (\pi D^2 H)^{0.916}
\]  

Information:

\[
\pi = 3.14
\]

D = trees diameter, height 1.3 m

H = trees height

How to measure each component refers to Serafin et al. [12] as follows Figure 1:

Plant and understorey biomass was measured by placing quadrants on the land under the trees, each side measuring 0.5 x 0.5 m, then harvesting trees Ø < 5 cm, herbs and grasses, weighing wet weight (BB), dry in the oven at temperature 80°C for 48 hours, weigh dry weight (BK).

Wood necromass were measured for length (T) and Ø (2R), weighing wet weight, drying in an oven at 80°C for 48 hours, weighing dry weight. Volume/V (cm\(^3\)) = \(\pi R^2 T\), BJ of wood (g/cm\(^3\)) = BK/V. Non-wood necromass is measured similar to the biomass of vegetation/understorey. Plant tissue carbon content, litter and necromass were analyzed by spectrophotometric methods. Soil organic matter (BO)
was measured by taking soil samples using iron boxes, each side measuring 10 cm, at a depth of 0-10 cm and 11-20 cm, dried, mashed, sieved 2 mm, analyzed for BO.

\[ D = \frac{K}{\pi} \]

\[ C = \alpha \times A \]

**Figure 1.** Measurement of tree height and diameter.

The estimated CO\(_2\) absorption capacity is calculated using the equation used by [13] Siwi (2012) in the following photosynthetic reactions:

\[ 6\text{CO}_2 + 6\text{H}_2\text{O} \rightarrow \text{C}_6\text{H}_{12}\text{O}_6 + 6\text{O}_2 \]

1 mol C\(_6\)H\(_{12}\)O\(_6\) = 6 mol CO\(_2\)

Massa CO\(_2\) = \frac{\text{Biomass Weight}}{\text{mass relative C}_6\text{H}_{12}\text{O}_6} \times 6\times \frac{\text{masa relative CO}_2}{\text{mol C}_6\text{H}_{12}\text{O}_6} \times \frac{\text{masa relative CO}_2}{\text{biomass weight} / 180} \times \frac{\text{biomass weight}}{1.47}

### 3. Results and discussion

#### 3.1 Cashew plant land conditions

**Table 1.** Land conditions for Wonogiri cashew plants in 2021.

| Age group | Elevation (m dpl) | Soil type 1) | Plant spacing (m) | Population ton/ha | Fruit colour | Understorey | Garden condition |
|-----------|------------------|--------------|-------------------|-------------------|--------------|-------------|-----------------|
| I         | 243              | latosol reddish brown | 6.3x3.4          | 466               | red          | Grasses, phytofarmaka | Semi treated |
| II        | 236              | latosol reddish brown | 6.1x5.2          | 315               | red          | Grasses, phytofarmaka | Semi treated |
| III       | 243              | latosol reddish brown | 7.9x6.4          | 198               | red          | Grasses | Semi treated |
| IV        | 260              | latosol reddish brown | 8.0x6.0          | 208               | red          | Grasses | Not treated |
| V         | 283              | latosol reddish brown | 10.6x6.0         | 220               | red          | Grasses | Not treated |

1) Base on The Tinjau Mapping
The cashew plantation in Pondok Village is located at an elevation of 236 - 283 m above sea level (asl). Grows on dry land with latosol reddish brown (alfisols) soil type. Planted with varying spacing, there is a tendency at a young age to be relatively dense but at an old age it is relatively rare. This variation resulted in the population per hectare not being up to standard. The condition of the garden was not well tended to the point (Table 1). At the beginning of planting, the farmers planted the plants with a relatively tight spacing, presumably so that the land would soon be covered, with time thinning was done. Trees that are maintained are selected based on the fertility of the trees, as a result the distance and population are not regular.

3.2 Carbon stock on plant cashew

The calculated carbon storage in each tree tends to increase as the age of the tree at KU4 then decreases from KU5 (Table 2 and Figure 2). Carbon storage of KU4 tends to be highest in the components of the surface of the soil (above ground) and below ground (below ground) and in soil carbon, but the litter component is achieved by KU5. At KU4 the plant conditions showed optimal growth and development, while at KU5 the plants showed an aging phase which was marked by the formation of bark, some branches died, the canopy was not tight, it was easier to fall off. This is indicated by the highest number of litter. Necromas components were not found, field observations indicated that necromas was used for firewood and / or for burning.

Table 2. Carbon stock on plant cashew.

| Age group | Above ground | Understorey | Litter | Necromas | Soil Carbon |
|-----------|--------------|-------------|--------|----------|-------------|
| I         | 1.605804     | 0.453410    | 0.028791 | 0        | 1.2282      |
| II        | 3.408063     | 0.511087    | 0.062110 | 0        | 1.3884      |
| III       | 3.805575     | 0.810140    | 0.119863 | 0        | 1.7424      |
| IV        | 6.155599     | 0.855733    | 0.208751 | 0        | 1.7922      |
| V         | 4.415619     | 0.719384    | 0.542136 | 0        | 1.2580      |

Carbon storage in woody plants in Gunungkidul people's forest was 69.221 kg/tree, acacia 21.06 kg/tree, 10.299 kg/tree, 4.83 kg/tree, sengon 1.39 kg/tree, while cashew plants are between 1,606 and 9,010 kg/m² [14]. Analysis of the relationship between the age group and carbon storage is quadratic of Y = -0.4882x² + 4.0174x - 0.4595 (R² = 0.8657). This equation shows that carbon storage in cashew plants increases with age, but the optimum is achieved at the age of 40 years and then decreases. This phenomenon shows the need for plant rejuvenation if carbon storage is desired. However, there are still other factors as much as 14% that affect the carbon storage capacity. The relationship between stand age and resin diameter in FMU Banyumas. Equation model Y = 7.3728389 + 1.4187729 X 0.02002839 X² (R² = 92.11%) [15].

![Figure 2. C-stock based on age group.](image-url)
3.3 \textit{CO}_2 absorption

The absorption of \textit{CO}_2 calculated based on the mass of \textit{CO}_2 from the photosynthesis process shows that the increasing age group of plants, the absorption of \textit{CO}_2 increases until a certain age then decreases (Table 3). This increase is thought to be related to an increase in leaf number, leaf thickness and canopy area. Cashew leaves are arranged in a flat circle at the end of the branch so that the chances of forming negative leaves are very small. Relatively thick leaves may have a lot of chloroplasts, with a dense canopy forming a large interception field to light [16], [17].

\textbf{Table 3.} Cashew plant \textit{CO}_2 uptake at age group (KU).

| Age group | Mass \textit{CO}_2 (kg/m$^2$) |
|-----------|-------------------------------|
| I         | 44.91                         |
| II        | 105.70                        |
| III       | 293.72                        |
| IV        | 583.54                        |
| V         | 485.06                        |

Analysis of the relationship between age groups and \textit{CO}_2 absorption has the same pattern as carbon storage, which is a quadratic character of $Y = -15.48x^2 + 228.7x - 213.22$ ($R^2 = 0.8636$) (Figure 3). This pattern can be understood because with increasing age the plant biomass which is formed as a result of photosynthesis increases but after the age of 40 the organs that support photosynthesis begin to decline. The decrease occurs due to the loss of many leaves due to the reduced performance of the meristem cells. As the cells get older, the rate of metabolism decreases [18].

\[ y = -15.48x^2 + 228.7x - 213.22 \]
\[ R^2 = 0.8636 \]

\textbf{Figure 3.} \textit{CO}_2 mass absorption.

The ability to absorb \textit{CO}_2 depends on the type and age [19]. Research conducted on mahogany trees (\textit{Swietenia mahagoni}) aged 11 years with a density of 940 trees/ha of 25.40 tons/ha/year, acacia (\textit{Acacia mangium}) with a density of 912 trees/ha of 23.64 tons/ha/year and sungkai (\textit{Peronema canescens}) aged 8 years with a density of 1016 trees/ha of 18.06 tons/ha/year. With calculations based on the average age group I-II and the same area, the ability of cashew plants to absorb \textit{CO}_2 is 75,305 tons/ha/year. As previously stated, the tree canopy system plays an important role in absorbing \textit{CO}_2. \textit{CO}_2 gas absorption in land use types in the form of fields is 657.00 tons \textit{CO}_2/ha/year; multi-type agroforestry 3679.20 - 7358.40 tons \textit{CO}_2/ha/year; forest 569.40 tons \textit{CO}_2/ha/year; plantation 569.40 tons \textit{CO}_2/ha/year [20].
4. Conclusion
Climate change affects carbon dioxide content. Cashew plants have the ability to store carbon and absorb CO$_2$ as the plant ages up to the age group 4, then it decreases. The pattern of the relationship between age groups and carbon storage is quadratic, the equation model is $Y = -0.4882x^2 + 4.0174x - 0.4595$ ($R^2 = 0.8657$), while with CO$_2$ absorption the pattern is the same as the equation model $Y = -15.48x^2 + 228.7x - 213.22$ ($R^2 = 0.8636$).

References
[1] Lee Y H, et al. 2020 The effect of concurrent elevation in CO2 and temperature on the growth, photosynthesis, and yield of potato crops PLoS ONE 15(10) e0241081
[2] Cortés-Calderón S, Mora F, Arreola-Villa F, and Balvanera P 2021 Ecosystem services supply and interactions along secondary tropical dry forests succession Forest Ecology and Management 482 e118858
[3] Zhao X et al. Accelerated biomethane production from lignocellulosic biomass: Pretreated by mixed enzymes secreted by Trichoderma viride and Aspergillus sp. Bioresource Technology 309 e123378.
[4] Huang H et al. Two-way long-range atmospheric transport of organochlorine pesticides (OCPs) between the Yellow River source and the Sichuan Basin, Western China,” Science of the Total Environment 651 230–3240
[5] Harihadi, Mahulette A S, Yahya S, and Wachjar A 2019 Measuring the potential of biomass, carbon storage, and carbon sink of forest cloves in IOP Conference Series: Earth and Environmental Science
[6] Fujisaki K et al. 2017 Soil carbon stock changes in tropical croplands are mainly driven by carbon inputs: A synthesis Agriculture, Ecosystems and Environment 259 147–158
[7] Nath A J et al. Quantifying carbon stocks and sequestration potential in agroforestry systems under divergent management scenarios relevant to India’s Nationally Determined Contribution Journal of Cleaner Production 281 124831
[8] Nogueira F C B, Dobe E K, Silva Filho J B, and Rodrigues L S 2021 Allometric equations to estimate aboveground biomass of Dalbergia ecearenus species in the Brazilian seasonally dry tropical forest Forest Ecology and Management 484 118920.
[9] Shen W, Li M, Huang C, Tao X, and Wei A 2018 Annual forest aboveground biomass changes mapped using ICESat/GLAS measurements, historical inventory data, and time-series optical and radar imagery for Guangdong province, China Agricultural and Forest Meteorology 259 23–38
[10] Li Y, Liu Y, Wu S, Wang C, Xu A, and Pan X 2017 Hyper-spectral estimation of wheat biomass after alleviating of soil effects on spectra by non-negative matrix factorization,” European Journal of Agronomy 84 58–66
[11] Vorster A G, Evangelista P H, Stovall A E L, and Ex S 2020 Variability and uncertainty in forest biomass estimates from the tree to landscape scale: The role of allometric equations Carbon Balance and Management 15 8
[12] Serafin J, Narkiewicz U, Morawski A W, Wrobel R J, and Michalkiewicz B 2017 Highly microporous activated carbons from biomass for CO2 capture and effective micropores at different conditions Journal of CO2 Utilization 18 73–79
[13] Suryanto P, Sadono R, Yohanifa A, Widyawan M H, and Alam T 2021 Semi-natural regeneration and conservation in agroforestry system models on small-scale farmers Biodiversitas 22 (2) 858–865
[14] Zas R, Quiroga R, Touza R, Vázquez-González C, Sampedro L, and Lema M 2020 Resin tapping potential of Atlantic maritime pine forests depends on tree age and timing of tapping Industrial Crops and Products 157 112940
[15] Liu X et al. 2019 Downscaling of solar-induced chlorophyll fluorescence from canopy level to photosystem level using a random forest model Remote Sensing of Environment 231 110772
[16] Yan G et al. 2019 Review of indirect optical measurements of leaf area index: Recent advances, challenges, and perspectives Agricultural and Forest Meteorology 265 390–411
[17] Siddiqui H, Sami F, and Hayat S 2020 Glucose: Sweet or bitter effects in plants-a review on current and future perspective Carbohydrate Research 487 107884
[18] Borek S, Paluch-Lubawa E, Pukacka S, Pietrowska-Borek M, and Ratajczak L 2017 Asparagine slows down the breakdown of storage lipid and degradation of autophagic bodies in sugar-starved embryo axes of germinating lupin seeds Journal of Plant Physiology 209 51–67
[19] Savage J A and Chuine I 2021 Coordination of spring vascular and organ phenology in deciduous angiosperms growing in seasonally cold climates New Phytologist 230 (5) 1700–1715
[20] Olorunfemi I E, Komolafe A A, Fasinmirin J T, and Olufayo A A 2019 Biomass carbon stocks of different land use management in the forest vegetative zone of Nigeria Acta Oecologica 95 45–56