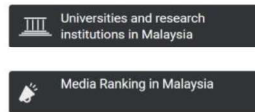


Journal of Sustainability Science and Management

COUNTRY

Malaysia



SUBJECT AREA AND CATEGORY

Environmental Science
└ Management, Monitoring, Policy and Law
└ Pollution

Social Sciences
└ Geography, Planning and Development

PUBLISHER

Universiti Malaysia Terengganu

H-INDEX

19

PUBLICATION TYPE

Journals

ISSN

26727226, 18238556

COVERAGE

2009-2022

INFORMATION

Homepage

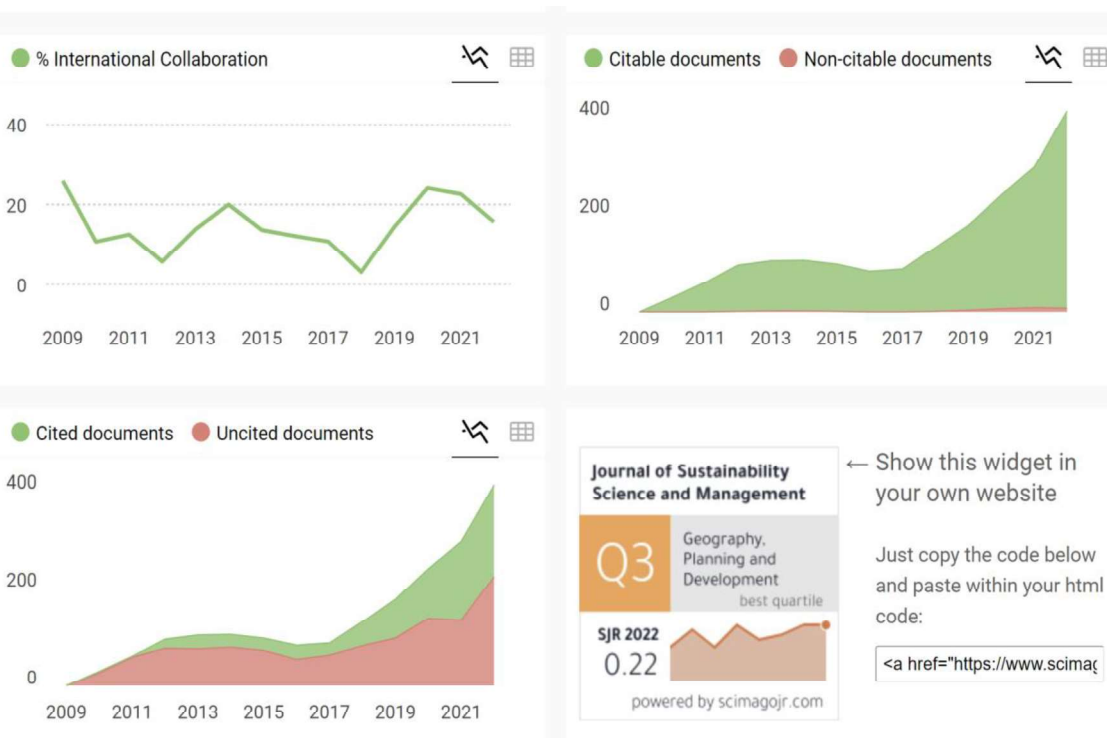
How to publish in this journal

jssmce@umt.edu.my



SCOPE

The Journal of Sustainability Science and Management is an Open-Access and peer-reviewed journal aims to publish scientific articles related to sustainable science; i.e. an interaction between natural sciences, social science, technologies and management for sustainable development and wise use of resources. We particularly encourage manuscripts that discuss contemporary research that can be used directly or indirectly in addressing critical issues and sharing of



Cover



Contents

Original Article

- 1-10 [Water Holding Capacity and Soil Organic Carbon in Teak \(*Tectona Grandis* Linn. F\) Agroforestry](#)
ANDI MASNANG, ASMANUR JANNAH, RATNA SARI HASIBUAN, RINI FITRI
- 11-35 [Sustainable Entrepreneurship Practices as Predictor of Micro Enterprises Performance in Rural Context: A Structural Equation Modelling Approach](#)
SITI FAHAZARINA HAZUDIN, SUHANOM MOHD ZAKI, MUHAMMED SOFFIQ SARIPIN, FAIZAN ABD JABAR, T. RAMAYAH AND NOOR IZAN MOHAMAD ADNAN
- 36-53 [Common Defects in Public Institutional Buildings in Malaysia](#)
MOHD ASHRAF MOHD FATEH* AND NURAINI SABIHAH NIKMAT
- 54-67 [Illegal Tortoiseshell Harvest of Hawksbill Turtles \(*Eretmochelys Imbricata*\) in Southeast Asia: Evidence from Baturua Reef, Semporna, Sabah, Malaysia](#)
JEETHVENDRA KIRISHNAMOORTHIE, NISHIZAWA HIDEAKI, ALIN JAMES, MUIN HUSSEIN AND JOSEPH JUANITA
- 68-87 [Metal Variations in Notched Threadfin Bream from Nearshore and Open Water Areas of Terengganu](#)
MUHAMMAD ROZAIMI MOHD ZAKI, SALWA SHAHIMI, CHONG JU LIAN, POH SENG CHEE, LOH ING HOE, JAYARAJ VIJAYA KUMARAN, WONG CHEEHO, EDINUR HISHAM ATAN, SIDDHARTHA PATI AND BRYAN RAVEEN NELSON
- 88-103 [Rainfall Intensity Classification in the East Coast of Malaysia Using Discriminant Analysis](#)
MOHAMAD AMEER IMRAN MOHD NOOR, MUHAMMAD AFIQ HALEK, AZWAN FAIZ LIM MUHAMMAD RAZWAN LIM, AND HASFAZILAH AHMAT
- 104-125 [Sustainability of Dryland, Farmers, and Local Industry: Dryland of Cassava Model](#)
NEVY FARISTA ARISTIN, AGUS PURNOMO AND SADEWA PURBA SEJATI
- 126-136 [Development Model of Prototype Buddhist Crematorium for Urban Community](#)

PHURIPANYO PHRAKHRUSANGHARAK, SITTISAKULJAROEN
SUNTHORN, PASIWIGO PHRAMEDHAVINAIYAROS AND CHAISUK
PERAVAT

- 137-150 [Oxidative Stress and Antioxidant Activities of Parachlorella Kessleri at Different Growth Phases](#)
NURUL SHAFIQA-YUSOF, SARAH NABILA AB GHAFAR, YEONG YIK
SUNG, HAZLINA AHAMAD ZAKERI, MOHD EFFENDY ABDUL WAHID
AND NORHAYATI YUSUF
- 151-166 [Hydrolysis of Food Waste and Production of Bioelectricity Using Single Chamber Microbial Fuel Cell for the Sustainable Future](#)
SIMPLISTE DUSABE, SRI RACHMANIA JULIASTUTI AND RADEN
DARMAWAN
- 167-185 [Effects of Various Soil Extract Fraction Types on the Growth of Marine Microalgae](#)
EMI FAZLINA HASHIM, KAZUHIRO KOMATSU, AKIO IMAI, HIDEMI
ONOUCHI, WAN MUHAMMAD IKRAM WAN MOHD ZAMRI, NOR
SUHAILA YAACOB, MASAHIRO OHTAKE, MUTSUMI SEKINE, AND
TATSUKI TODA
- 186-198 [Evaluation of Dietary Microalgae in the Culture of Acartia Steueri \(Copepoda, Calanoida\)](#)
YOSHIKI TAKAYAMA, FATIMAH MD. YUSOFF AND TATSUKI TODA
- 199-216 [Comparative Analysis of Ulva Lactuca and Gracilaria Corticata for Formulation of Bakery Products](#)
KAKOLI BANERJEE, ARCHANA SNEHASINI TURUK AND BALU ALAGR
VENMATHI MARAN MARAN

Short Communication

- 217-225 [Meaning of Nyarai Salibutan Ecotourism in Environmental Communication](#)
MIRA HASTI HASMIRA, ERI BARLIAN AND ALDRI FRINALDI

Dewan Redaksi

Editorial Board

CHIEF EDITOR

Mhd Ikhwanuddin Abdullah, **Universiti Malaysia Terengganu, Malaysia**

[Scopus](#) | [Web of Science](#)

DEPUTY CHIEF EDITOR

Lam Su Shlung, **Universiti Malaysia Terengganu, Malaysia**

[Scopus](#) | [Web of Science](#)

MANAGING EDITOR

Aziz Ahmad, **Universiti Malaysia Terengganu, Malaysia**

[Scopus](#) | [Web of Science](#)

MEMBERS

Anne E. Daly, **University of Canberra, Australia**

[Scopus](#) | [Web of Science](#)

Frederick H. Sheldon, **Louisiana University, United States of America**

[Scopus](#) | [Web of Science](#)

He Jian Guo, **Sun Yat-Sen University, China**

[Scopus](#) | [Web of Science](#)

Jerome Hui, **Chinese University of Hong Kong, China**

[Scopus](#) | [Web of Science](#)

Mohd Tajuddin Abdullah, **Universiti Malaysia Terengganu, Malaysia**

[Scopus](#) | [Web of Science](#)

WATER HOLDING CAPACITY AND SOIL ORGANIC CARBON IN TEAK (*Tectona grandis* Linn. F) AGROFORESTRY

ANDI MASNANG^{1*}, ASMANUR JANNAH¹, RATNA SARI HASIBUAN² AND RINI FITRI³

¹Faculty of Agriculture, University of Nusa Bangsa, Bogor, Indonesia. ²Faculty of Forest, University of Nusa Bangsa, Bogor, Indonesia. ³Faculty of Landscape Architecture and Environmental Technology, Department of Landscape Architecture, Universitas Trisakti, Jakarta, Indonesia.

*Corresponding author: andimasnang65@gmail.com

Submitted final draft: 17 April 2023

Accepted: 17 April 2023

<http://doi.org/10.46754/jssm.2023.07.01>

Abstract: Agroforestry is typically used to environmentally and economically optimize and efficiently use land through diversification of commodities over time on the same field. The research objective was to assess the water-holding capacity and soil organic carbon content of land used to cultivate teak trees. This study surveyed teak monoculture (TM) sites aged 11 years as well those teak that were combined with three types agroforestry – teak-arrowroot (TA), teak-taro (TT), teak-cassava (TC) for each age seven years, and two types of monocultures – maize monoculture (MM) and paitan elephant grass (G). Observations on each land type, measuring 20 m by 20 m, were replicated thrice. The results showed that teak monoculture (TM) has the lowest soil bulk density, which is accompanied by an increase in water holding capacity. The TM land was the best with the lowest bulk density, soil porosity, field capacity water content and the highest water holding capacity, significantly different from the teak-cassava (TC). The highest total biomass and C-biomass in monoculture teak was 440.45 Mg ha⁻¹ and 202.60 Mg ha⁻¹, which are significantly different from teak produced on other land types. Soil organic carbon content decreased according to soil depth except for teak-arrowroot agroforestry and teak monoculture.

Keywords: Teak agroforestry, bulk density, water holding capacity, soil organic C.

Abbreviations: TM (teak monoculture); TA (teak-arrowroot); TT (teak-taro); TC (teak cassava); MM (maize monoculture); G (grass).

Introduction

The world population is currently around 7.9 billion, and is estimated to increase to 9.3 billion by 2050 and about 11 billion by 2100 (Madkour *et al.*, 2022). The increase in population will result in rising demand for wood and food, putting pressure on agricultural land and forest areas that have decreased due to the conversion to other uses. Meeting these needs would require optimizing space and time of land use. One type of land use that can meet the need for housing and food is agroforestry. According to Tully and Ryals (2017a) agroforestry is a dynamic, ecologically oriented strategy for managing natural resources that involves integrating trees into agricultural and grazing fields to boost smallholder production and diversify it for greater social, economic, and environmental advantages. Cropping patterns in agroforestry

systems, on the same land unit and at the same or different times, allow the continuity of sustainable crop production diversity (Ferreiro-Domínguez *et al.*, 2016; Mosquera-Losada *et al.*, 2018).

These aims can be realized by combining teak agroforestry with food crops. According to Magalhães *et al.*, (2013), the monoculture of five-year-old teak is a system that is more like forests for storing nutrients of cocoa teak, forestry (five-years teak), eight-years-old teak, agricultural areas (teak, cocoa, and pasture) and pasture. An agroforestry system can realize sustainable agriculture's characteristics because it can produce almost like a multistorey natural forest (Hastuti & Sufiadi, 2017). Organic carbon content is generally high in natural soils under grass or forest cover. An agroforestry system with a multi-level canopy protects the soil

surface against damage caused by raindrops' kinetic energy (Idris & Mahrup, 2017; Tavares *et al.*, 2018). Agroforestry plays a role in soil conservation (Yasin *et al.*, 2019) to increase groundwater availability (Tully & Ryals, 2017a). Also, the intake of organic residues from falling leaves of trees and under-standing plants will function as mulch (Joslin *et al.*, 2019). Their decomposition will increase organic matter content in the soil (Jacobs *et al.*, 2017). Different vegetation has different abilities to anchor carbon (Singh *et al.*, 2020) and interact with the soil to produce organic matter that provides nutrients (Tully & Ryals, 2017b) and determines soil quality (Kurien *et al.*, 2021).

Land management for teak agroforestry is quite fluid and heavily impacted by farmer experience. Teak was initially grown as a monoculture, but eventually farmers discovered that teak can be intercropped with food crops as an extra source of revenue. Farmers, however, encounter issues with the availability of water for food crops when managing teak agroforestry. Above ground, it is simple to see how teak agroforestry works. Below ground, however, it is more difficult to see how they affect drought sensitivity through altering the qualities of the soil. This study examined the effects of different types of teak-based agroforestry on soil bulk density, soil organic carbon, and vegetation carbon. The research objective was to assess the water holding capacity and soil organic carbon content of the teak-based land-use type. The hypothesis tested is that the type of teak agroforestry causes differences in water storage capacity and soil organic carbon.

Materials and Methods

Sampling Sites

The research was carried out from November 2020 to February 2021 in the University of Nusa Bangsa's experimental farm. The research location is administratively included in the Cogreg village area, Ciseeng sub-district, Bogor district, West Java, Indonesia. The land area of 11 ha is located between 6°25'40'SL and

106°41'05'EL. The elevation is at 150 masl, and the slope ranges from 3-8%. Soil type is Inceptisol at pH 5. The average rainfall is 2750 mm per year, and the average daily temperature is 28°C with an average minimum of 23°C and a maximum of 38°C.

Based on observations at the research site, there were six types of land use based on teak trees (*Tectona grandis* Linn. F) aged 7 and 11 years on a land area of 11 ha. Monoculture of 11 year-old-teak took up the most land, at 7 ha. A hectare each was taken up by agroforestry of teak trees combined with other plants, which are teak with taro (*Colocasia esculent* Linn), arrowroot (*Maranta arundinacea*), and cassava (*Manihot esculenta*) The spacing for each of teak tree was 2 m x 5 m, taro 1 m x 1 m, arrowroot and cassava are 60 cm x 60 cm. Two types of non-timber monoculture land use were also found, namely maize (*Zea mays*), spaced 60 cm x 60 cm covering an area of 0.5 ha and paitan elephant grass (*Axonopus compressus*) surrounding an area of 0.5 ha. At the time of observation, the intercropping plants were three months old. The farmers around the land cultivated intercropping plants continuously since the teak plants are planted.

The 6 types of land use observation plots were teak monoculture (TM), teak and taro combination agroforestry (TT), teak and arrowroot combination agroforestry (TG), teak and cassava combination agroforestry (TC), maize monoculture (MM) as control plot and paitan elephant grass monoculture (G) (Figures 1 and 2). Observations were repeated three times each to obtain 18 units of observation plots. In each plot, six disturbed and undisturbed soil samples were collected. Sampling of undisturbed soil to determine of soil density was done at a depth of 0-30 cm. As much as 1 kg of disturbed soil samples were taken at a depth of 0-30 cm and 30-60 cm to determine the water content and C-organic content of the soil. Determination of soil bulk density, water content and C-organic content was carried out at the Nusa Bangsa university laboratory. Vegetation biomass and carbon content were also measured.

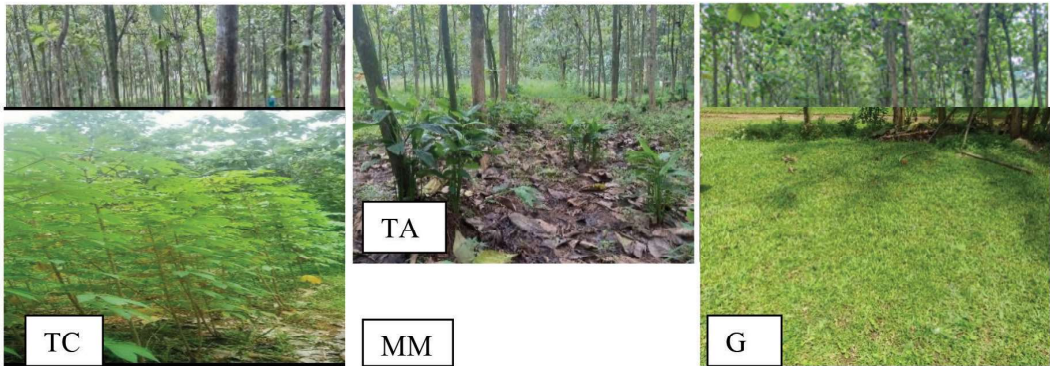


Figure 1: Plot measurement of teak monoculture (TM), teak-arrowroot (TA), teak-taro (TT), teak-cassava (TC), maize monoculture (MM), paitan elephant grass (G)

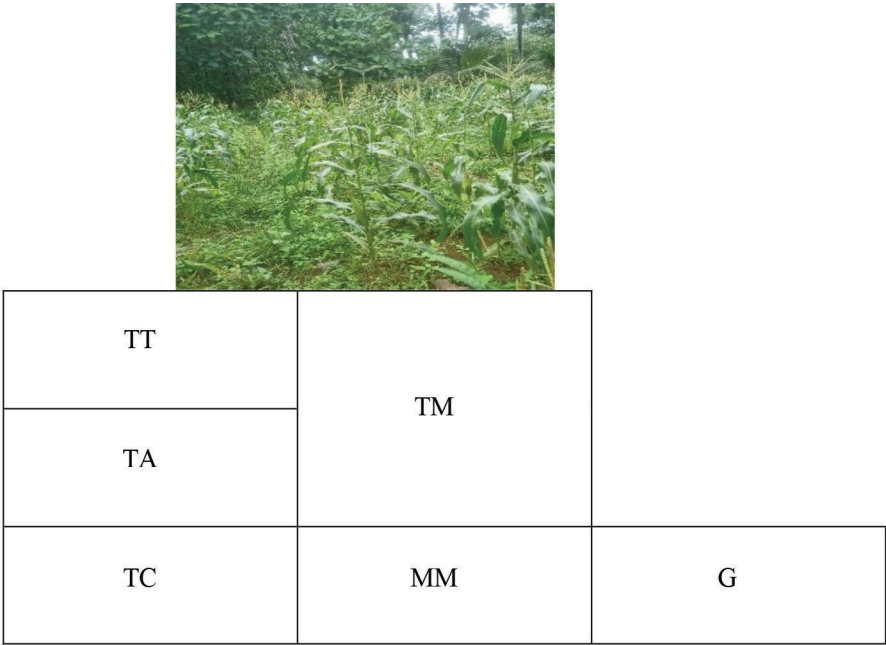


Figure 2: Planting layout and research design of monoculture teak (TM), teak-arrowroot (TA), teak-taro (TT), teak-cassava (TC), maize monoculture (MM), paitan elephant grass (G)

Soil Bulk Density (g cm^{-3}).

Soil bulk density was measured following the procedure of Blake and Hartge (1986). Undisturbed soil samples were taken using a ring sample with an inner diameter of 7.5 mm and a height of 4 mm. Based on soil bulk density data, the porosity (%) is calculated with the assumption that the particle density of mineral soil is 2.65 g cm^{-3}

Soil Water Content at a Depth of 0-30 cm and 30-60 cm (%).

As much as 1 kg of soil sample was taken using a soil drill that had been marked for a depth of 30 cm and 60 cm. Water content was measured in the laboratory using the gravimetric method (Hillel, 1980).

Field Water Content Capacity (%).

The soil was saturated with water. When the water stops dripping, the soil sample is then heated at a temperature of 105°C for 24 hours (Hillel, 1980).

Soil Water Holding Capacity (mm). The water holding capacity in the soil was calculated gravimetrically by Hillel (1980). The result of the water content was multiplied by the depth of the soil and the area of the land (Masnang, 2011).

Soil C-organic (%). Soil C-organic content at depths of 0-30 cm and 30-60 cm were determined by the Walkley and Black method described by Naelson & Sommers (1996). The soil carbon content is calculated using the equation according to BSN (2011):

$$C_t = K_d \times \rho \times \% C;$$

Where,

C_t = soil carbon content (g cm^{-2})

K_d = depth of soil sample (cm)

$\% C$ organic

= percentage of carbon content measured in laboratory.

ρ = bulk density (g cm^{-3})

C_{soil} = $C_t \times 100 \dots (\text{Mg ha}^{-1})$;

Where,

C_{soil} = soil organic content per hectare, expressed in tonnes per hectare (Mg ha^{-1})

C_t = soil carbon content (g cm^{-2})

100 = conversion factor from g cm^{-2} to Mg ha^{-1} .

Biomass and Vegetation Carbon Content.

Sampling was carried out on each plot measuring 20 m x 20 m. Vegetation biomass is measured using the allometric equation according to Brown as described by Makinde *et al* (2017) in calculating teak biomass. The allometric equation can assess forests' ability to absorb CO_2 without having to cut down trees. The observation that is measured is dbh (diameter at breast height or diameter as high as 1.3 m from the ground). The equation to calculate biomass

according to Brown (1997) for trees with a diameter of more than 5 cm is as follows:

$$Y = 0.118 D^{2.53} \text{ at } D = 5\text{-}148 \text{ cm}$$

Carbon content is calculated using the equation:

$$C = 0.46 \times Y$$

Where:

Y = total tree biomass (kg/tree),

D = trunk diameter at breast height (130 cm),

C = carbon content (kg/tree)

For the measurement of biomass of maize, cassava and arrowroot, 200 grams of each plant was sampled, then dried in an oven at 80°C for 48 hours, then weighed to determine oven-dry biomass.

Data Analysis

Data were analyzed descriptively by calculating the mean and standard deviation of each parameter. Analysis of variance (ANOVA) was carried out to identify or test whether there are differences in land use for the parameters observed. The Tukey HSD test $P < 0.05$ was then carried out to determine if the analysis of variance shows a significant difference between variables. The statistical analysis was done using the STAR software (R-Packages 1.5 STAR 2.0.) (Statistical Tool for Agricultural Research), developed by the Department of Plant Breeding Genetics and Biotechnology, IRRI (International Rice Research Institute), Manila, Philippines.

Results and Discussion**Characteristics of Soil Physical Properties and Water Storage Capacity**

Land covered by good vegetation can improve the structure of more loose soil and granular soil aggregates. More loose soil will lead to lower soil density and higher porosity. The results of statistical analysis in Table 1 show that teak monoculture (TM) significantly affects the bulk density, porosity, and water storage capacity of land. When compared with teak-arrowroot (TA), teak-taro (TT), teak-cassava (TC), maize monoculture (MM), and paitan elephant grass

(G), TM land has lower soil density and higher overall porosity and higher water storage capacity. The soil weight in TM land was 1.19 g cm^{-3} , which is lower than the 1.27 g cm^{-3} recorded in TA, 1.32 g cm^{-3} in TC, 1.45 g cm^{-3} in MM, 1.32 g cm^{-3} TT and 1.37 g cm^{-3} in elephant grass. The pattern of bulk density in teak monoculture is similar to the soil density in natural forests as described by (Makinde *et al.*, 2017). In natural forests, the bulk density is 1.16 g cm^{-3} and 1.28 g cm^{-3} on natural grass. The bulk density of soil is an indicator of soil compaction. Soil compaction is undesirable because it can reduce soil aeration and water holding capacity, and impedes root penetration thereby, curbing a plant's ability to harvest water.

The low bulk density of TM causes the porous surface soil layer to accelerate water movement and spread. Data in Table 1 and Figure 3 show that the level of porosity in TM

is 54.91%, and it has the highest water holding capacity as 32.94 mm. TA has the next highest water holding capacity at 31.37 mm, followed by TT (30.19 mm), TC (27.27 mm), MM (30.11 mm) and G (29.10 mm). Enhancement soil porosity can help soil aeration, thus facilitating the circulation of air and water in the ground.

Total Biomass and Carbon Biomass

The total biomass and total carbon biomass in TM were higher than the total biomass in TA, TT, TC, MM and G (Table 2). The TC land produced $175.20 \text{ Mg ha}^{-1}$ of biomass and 80.59 Mg ha^{-1} of total vegetation carbon, which is the higher compared to TA and TT. TC also has high soil organic C content (Figure 4 and Figure 5). The difference in total biomass and total vegetation carbon is because soil organic C comes from organic matter resulting from weathering of

Table 1: Bulk density, porosity, water content field capacity dan water holding capacity on the type of land use, namely maize monoculture (MM), teak-arrowroot (TA), teak monoculture (TM), teak-cassava (TC), teak-taro (TT), and paitan elephant grass (G)

Land Use Type	Bulk Density (g.cm^{-3})	Porosity (%)	Water Content Field Capacity (%)	Water Holding Capacity Depth 60 cm (mm)
MM	$1.32 \pm 0.10^{\text{ab}}$	$50.18 \pm 3.62^{\text{ab}}$	$44.14 \pm 2.07^{\text{ab}}$	$30.11 \pm 2.17^{\text{ab}}$
TA	$1.27 \pm 0.06^{\text{ab}}$	$52.29 \pm 2.20^{\text{ab}}$	$49.30 \pm 3.04^{\text{a}}$	$31.37 \pm 1.32^{\text{ab}}$
TM	$1.19 \pm 0.02^{\text{b}}$	$54.91 \pm 0.98^{\text{a}}$	$44.65 \pm 0.85^{\text{ab}}$	$32.94 \pm 0.58^{\text{a}}$
TC	$1.45 \pm 0.02^{\text{a}}$	$45.45 \pm 0.57^{\text{b}}$	$39.06 \pm 1.34^{\text{bc}}$	$27.27 \pm 0.34^{\text{b}}$
TT	$1.32 \pm 0.05^{\text{ab}}$	$50.33 \pm 1.97^{\text{ab}}$	$49.25 \pm 1.99^{\text{a}}$	$30.19 \pm 1.19^{\text{ab}}$
G	$1.37 \pm 0.15^{\text{ab}}$	$48.50 \pm 5.81^{\text{ab}}$	$35.23 \pm 3.80^{\text{c}}$	$29.10 \pm 3.49^{\text{ab}}$

*Different letters along column indicate significant differences ($p < 0.05$) according to Tukey's test.

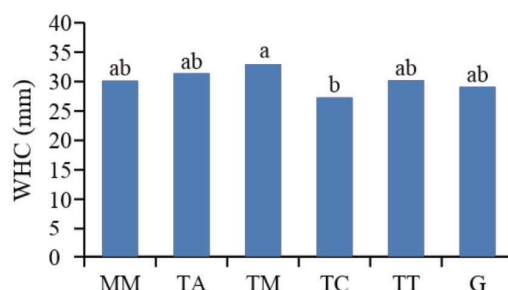


Figure 3: Water holding capacity on the type of land use, namely maize monoculture (MM), teak-arrowroot (TA), teak monoculture (TM), teak-cassava (TC), teak-taro (TT), and paitan elephant grass (G)

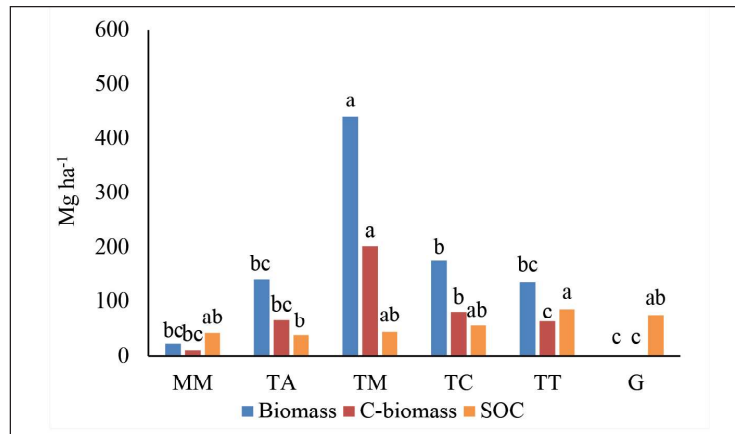


Figure 4: Biomass, biomass carbon and soil organic carbon on the type of land use, namely maize monoculture (MM), teak-arrowroot (TA), teak monoculture (TM), teak-cassava (TC), teak-taro (TT), and paitan elephant grass (G)

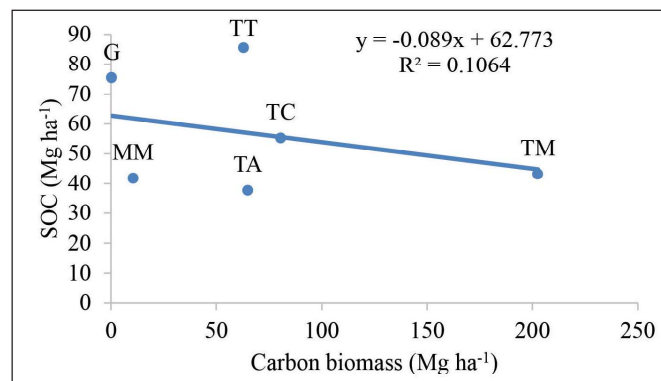


Figure 5: The relationship between biomass carbon and soil organic carbon on the type of land use, namely maize monoculture (MM), teak-arrowroot (TA), teak monoculture (TM), teak-cassava (TC), teak-taro (TT), and paitan elephant grass (G)

vegetation and litter and is influenced by the type of vegetation.

Taro plants grow well under the shade. In the TT type, although the biomass (13.67 Mg ha^{-1}) and vegetation carbon (62.86 Mg ha^{-1}) were lower than that of the TA, TC, the soil organic C content was the highest at 1.64%. This is because taro leaf litter decomposes faster due to its morphology, which is thinner and more succulent. (Bouaravong *et al.*, 2017).

Biomass in monoculture teak was $440.45 \text{ Mg ha}^{-1}$ and biomass carbon of $202.60 \text{ Mg ha}^{-1}$ was the highest compared to biomass in TA, TC, TT, MM and G (Table 2). The high biomass

carbon in TM was not closely related to the soil organic C content (Figure 5) which was 1.01% lower than the C-organic in the TT type.

Research by Santosa *et al.* (2020) showed that the carbon content in teak leaves that had just fallen from various sites was around 50.92% and Nitrogen content was 1.28% so that C/N ratio ranges in the 40s, which is very high. This results in a slow decomposition process. If the C/N ratio is high, microorganisms take a long time to degrade matter (Purnomo *et al.*, 2017). Research by Yuliani and Rahayu, (2016) show that low-quality organic teak leaves have a low P content, but a high C/N ratio of 33.19,

Table 2: Total biomass, C-biomass, SOC, and Total SOC on the type of land use, namely maize monoculture (MM), teak-arrowroot (TA), teak monoculture (TM), teak-cassava (TC), teak-taro (TT), and paitan elephant grass (G)

Land Use Type	Total Biomass (Mg ha ⁻¹)	Total C-biomass (Mg ha ⁻¹)	SOC (%) Depth 0-30cm	SOC (%) Depth 30-60cm	Total SOC (Mg ha ⁻¹)
MM	22.82±1.79 ^{bc*}	10.50±0.83 ^{bc}	0.79±0.11 ^b	0.50±0.16 ^d	41.81±11.89 ^{ab}
TA	141.23±10.51 ^{bc}	64.96±4.83 ^{bc}	0.78±0.10 ^b	0.83±0.03 ^{bc}	37.75±6.86 ^b
TM	440.45±138.74 ^a	202.60±63.82 ^a	1.01±0.39 ^{ab}	1.11±0.14 ^{ab}	43.21±15.6 ^{ab}
TC	175.20±52.49 ^b	80.59±24.15 ^b	0.88±0.36 ^b	0.78±0.05 ^{cd}	55.30±23.23 ^{ab}
TT	136.67±36.75 ^{bc}	62.86±16.91 ^b	1.64±0.11 ^a	1.18±0.07 ^a	85.61±10.32 ^a
G	0.86±0.08 ^c	0.39±0.04 ^c	1.32±0.16 ^{ab}	0.85±0.17 ^{bc}	75.39±22.29 ^{ab}

*Different letters along column indicate significant differences ($p < 0.05$) according to Tukey's test.

exceeding the critical limit of the C/N ratio for N and C mineralization, which is 25-30.

The results of the study by Jain & Ansari (2013) reveal that in teak plantations, aboveground biomass containing the highest carbon stock (214.7 Mg C ha⁻¹) has an average annual carbon holding capacity of 19.5 C Mg. ha⁻¹ year⁻¹, equivalent to 70.6 CO₂ Mg ha⁻¹ year⁻¹ which is much larger than secondary forest and cocoa plantations.

Soil Organic Carbon

The results showed that TT agroforestry had the most affect on soil organic carbon content (Table 2). The highest soil organic C content was at teak-taro (TT) both at a depth of 0-30

cm and 30-60 cm, at 1.64% and 1.18%. These values are not significantly different from TM's, which are at 1.01% and 1.11% at the depth same. Soil organic C decreased according to soil depth for G, TT, TC and MM (Figure 6). According to (Ketema & Yimer, 2014; Khaki *et al.*, 2016) in general, soil organic carbon content in the top layer is higher and decreases according to soil depth.

Taro-teak agroforestry increases soil organic matter through decomposing vegetation as deciduous understorey fall to the soil surface. Soil organic C-values were higher in taro agroforestry than cassava and arrowroot agroforestry. This can be due to the thinner taro leaves littering the ground and the higher water

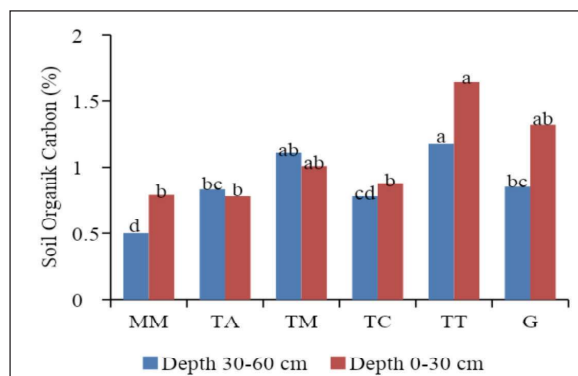


Figure 6: Soil organic carbon content at depths of 0-30 cm and 30-60 cm on the type of land use, namely maize monoculture (MM), teak-arrowroot (TA), teak monoculture (TM), teak-cassava (TC), teak-taro (TT), and paitan elephant grass (G)

content in the taro leaf midrib. The soil organic C content in the teak-arrowroot and cassava, maize and teak monocultures was not significantly different. As with taro, arrowroot can also grow to adapt to shade, such as under tree stands so that it has the potential to be developed on forest land (Sudomo *et al.*, 2019; Djaafar *et al.*, 2010). The rate of decomposition, the activity of soil microorganisms, and the amount of organic matter in the soil all have a significant impact on the level of organic carbon. The amount of soil organic matter that decomposes is greatly determined by soil temperature, moisture, and microorganism activity, which are in turn greatly dependent on the amount of plant and litter that covers the soil. In monoculture maize, the soil's surface is more open so loss of organic material and nutrients is higher, while the input or addition is less.

Agroforestry systems can maintain soil organic matter content in the top layer through weathering of litter on the soil surface (Khaki *et al.*, 2016). Regular trimming of the tree canopy adds to the soil surface litter, and its decomposition maintains or adds to the soil organic matter content. Arévalo & Martí (2020) analyzed the elements in teak leaf pruning, and found the highest carbon content of around 46.2%.

Conclusion

Land used for teak monoculture has the lowest soil bulk density, which is accompanied by an increase in water holding capacity. Teak monoculture land was the best type with the lowest bulk density, soil porosity, field capacity water content and the highest water holding capacity. The highest total biomass and C-biomass in teak monoculture of 440.45 Mg ha⁻¹ and 202.60 Mg ha⁻¹ were significantly higher than other land use types. However, this was not followed by an increase in soil organic content of 1.01%, which was lower than C-organic in the type of teak-taro agroforestry by 1.64%. Soil organic carbon content decreased according to soil depth except for teak-arrowroot agroforestry and teak monoculture. Soil organic carbon at

a depth of 30-60 cm in teak monoculture was significantly different from that of TC, MM and G.

Acknowledgements

We want to thank the institute for research and community service at the University of Nusa Bangsa for their support. Our gratitude also to Sumanto, Fuji Ardiansyah, Heri Purwanto, who helped collect data in the field and Asep, who helped in the analysis in the laboratory.

References

- Blake, G. R., & Hartge, K. H. (1986). Bulk density. In Klute, A. (Ed.), *Methods of Soil Analysis: Part 1—Physical and Mineralogical Methods* (2nd ed., pp. 363-375). Soil Science Society of America, American Society of Agronomy: Madison.
- Standar Nasional Indonesia (SNI). (2011). *Pengukuran dan penghitungan cadangan karbon –Pengukuran lapangan untuk penaksiran cadangan karbon hutan* (ground based forest carbon accounting). Badan Standadisasi Nasional, Jakarta. (in Indonesian).
- Brown, S. (1997). Estimating biomass and biomass change of tropical forests: A primer. *FAO Forestry Paper*, 134.
- Bouaravong, B., Dung, N. N. X., & Preston, T. R. (2017). Effect of biochar and biodigester effluent on yield of Taro (*Colocasia esculenta*) foliage. *Livestock Research for Rural Development*, 29(4), 69 ref.6.
- Djaafar, T., Sarjiman, S., & Pustika, A. (2010). Pengembangan budi daya tanaman Garut dan teknologi pengolahannya untuk mendukung ketahanan Pangan. *Jurnal Penelitian Dan Pengembangan Pertanian*, 29(1), 25-33. (in Indonesian).
- Ferreiro-Domínguez, N., Rigueiro-Rodríguez, A., Rial-Lovera, K. E., Romero-Franco, R., & Mosquera-Losada, M. R. (2016). Effect of grazing on carbon sequestration and tree

- growth that is developed in a silvopastoral system under wild cherry (*Prunus avium* L.). *Catena*, 142, 11-20.
- Hastuti, I. N., & Sufiadi, E. (2017). Studi perbandingan Propil tumbuhan Agroforestry di Perum Perhutani dengan Lahan Milik di Kabupaten Sumedang. *Paspalum: Jurnal Ilmiah Pertanian*, 4(1), 29-39. (in Indonesian).
- Idris, M. H., & Mahrup. (2017). Changes in hydrological response of forest conversion to agroforestry and rainfed agriculture in Renggung Watershed, Lombok, Eastern Indonesia. *Jurnal Manajemen Hutan Tropika*, 23(2), 102-110.
- Jacobs, S. R., Breuer, L., Butterbach-Bahl, K., Pelster, D. E., & Rufino, M. C. (2017). Land use affects total dissolved nitrogen and nitrate concentrations in tropical montane streams in Kenya. *Science of the Total Environment*, 603-604, 519-532. <https://doi.org/10.1016/j.scitotenv.2017.06.100>
- Jain, A., & Ansari, S. A. (2013). Quantification by allometric equations of carbon sequestered by *Tectona grandis* in different agroforestry systems. *Journal of Forestry Research*, 24(4), 699-702.
- Joslin, A. H., Vasconcelos, S. S., Oliveira, F. de A., Kato, O. R., Morris, L., & Markewitz, D. (2019). A slash-and-mulch improved-fallow agroforestry system: Growth and nutrient budgets over two rotations. *Forests*, 10(12), 1-25.
- Ketema, H., & Yimer, F. (2014). Soil property variation under agroforestry based conservation tillage and maize based conventional tillage in Southern Ethiopia. *Soil and Tillage Research*, 141(1-3), 25-31.
- Khaki, B. A., Wani, A. A., Bhardwaj, D. R., & Singh, V. R. R. (2016). Soil carbon sequestration under different agroforestry land use systems. *Indian Forester*, 142(8), 734-738.
- Kurien, V. T., Thomas, E., Prasanth Narayanan, S., & Thomas, A. P. (2021). Soil organic carbon pool under selected tree plantations in the Southern Western Ghats of Kerala, India. *Tropical Ecology*, 62(1), 126-138.
- Madkour, M., Salman, F. M., El-Wardany, I., Abdel-Fattah, S. A., Alagawany, M., Hashem, N. M., Abdelnour, S. A., El-Kholy, M. S., & Dhama, K. (2022). Mitigating the detrimental effects of heat stress in poultry through thermal conditioning and nutritional manipulation. In *Journal of Thermal Biology*, 103, 1-11. <https://doi.org/10.1016/j.jtherbio.2021.103169>
- Magalhães, S. S. A., Weber, O. L. S., dos Santos, C. H., & Valadão, F. C. A. (2013). Nutrient stocks under different land use systems of a soil in Colorado do oeste-RO [Estoque de nutrientes sob diferentes sistemas de uso do solo de Colorado do oeste-RO]. *Acta Amazonica*, 43(1), 63-72.
- Makinde, E. O., Ogundeko, M. O., & Womiloju, A. A. (2017). Geospatial assessment of carbon sequestration in Oluwa Forest, South-West Nigeria. *Nigerian Journal of Environmental Sciences and Technology*, 1(1), 188-202.
- Masnang, A. (2011). *Kajian Tingkat Erosi, Sekuestrasi Karbon dan Daya Simpan Air pada Berbagai Tipe Penggunaan Lahan di Sub DAS Jenneberang Hulu*. [Disertasi]. Institut Pertanian Bogor, Bogor. (in Indonesian).
- Mosquera-Losada, M., Santiago-Freijanes, J., Moreno, G., Herder, den M., Aldrey, J., Rois-Diaz, M., Dominguez, N., Pantera, A., & Rigueiro-ZZ. (2018). *Agroforestry definition and practices for policy makers*. Agroforestry Policies 104 4th European Agroforestry Conference Agroforestry as Sustainable Land Use. Published by the European Agroforestry Federation and the University of Santiago de Compostela in Lugo (Spain), ISBN: 978-84-09-02384-4
- Naelson, D. W., & Sommers, L. E. (1996). Total Carbon and Organic Matter. In Sparks, D. L., Page, A.L., Helmke, P. A., Loeppert, R. H., Soltanpour, P. N., Tabatabai, M.

- A., Johnston, C. T., Summer, M. E (Eds.), *Methods of soil analysis, Part 3, Chemical Methods*, 5.3. American Society of Agronomy: Madison, WI, USA, 1996; pp. 1004-1005.
- Pérez Arévalo, J. J., & Velázquez Martí, B. (2020). Characterization of teak pruning waste as an energy resource. *Agroforestry Systems*, 94(1), 21-250.
- Purnomo, E. A., Sutrisno, E., & Sumiyati, S. (2017). Pengaruh variasi C/N rasio terhadap produksi kompos dan kandungan Kalium (K), Pospat (P) dari batang pisang dengan kombinasi kotoran sapi dalam sistem vermicomposting. *Jurnal Teknik Lingkungan*, 6(2), 1-15. (in Indonesian).
- Santosa, S., Umar, M. R., Priosambodo, D., & Santosa, R. A. P. (2020). Estimation of biomass, carbon stocks and leaf litter decomposition rate in teak *Tectona grandis* linn plantations in city forest of hasanuddin university, Makassar. *International Journal of Plant Biology*, 11(8541), 32-35.
- Singh, A. K., Sahu, C., & Sahu, S. K. (2020). Carbon sequestration potential of a teak plantation forest in the Eastern Ghats of India. *Journal of Environmental Biology*, 41(4), 770-775.
- Sudomo, A., Sebastian, G. E., Perdana, A., Prameswari, D., & Roshetko, J. M. (2019). Intercropping of *Zingiber officinale* Var. *Amarum* on teak silviculture in Karangduwet, Paliyan Gunung Kidul Yogyakarta. IOP Conference Series: *Earth and Environmental Science*, 250(1), 1-7.
- Tavares, P. D., Da Silva, C. F., Pereira, M. G., Freo, V. A., Bieluczyk, W., & Da Silva, E. M. R. (2018). Soil quality under agroforestry systems and traditional agriculture in the atlantic forest biome. *Revista Caatinga*, 31(4), 954-962.
- Tully, K., & Ryals, R. (2017a). Agroecology and sustainable food systems nutrient cycling in agroecosystems: Balancing food and environmental objectives. *Agroecology and Sustainable Food Systems*, 41(7), 880-884.
- Tully, K., & Ryals, R. (2017b). Nutrient cycling in agroecosystems: Balancing food and environmental objectives. *Agroecology and Sustainable Food Systems*, 41(7), 761-798.
- Yasin, G., Nawaz, M. F., Martin, T. A., Niazi, N. K., Gul, S., & Yousaf, M. T. Bin. (2019). Evaluation of agroforestry carbon storage status and potential in irrigated plains of Pakistan. *Forests*, 10(8), 1-13.
- Yuliani, & Rahayu, Y. S. (2016). Pemberian seresah daun jati dalam meningkatkan kadar hara dan sifat fisika tanah pada tanah berkapur. *Prosiding Seminar Nasional Biologi, January*. 1-6. (in Indonesian).