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Floristic composition and carbon sequestration of traditional agroforestry on peatland in Rimbo Panjang, Kampar, Riau, Indonesia

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Abstract. *Isda MN, Fatonah S, Yulminarti, Oktarina NZ, Roslim DI. 2025. Floristic composition and carbon sequestration of traditional agroforestry on peatland in Rimbo Panjang, Kampar, Riau, Indonesia. Biodiversitas 26: 470-479.* Trees in agroforestry systems contribute to long-term carbon sequestration, helping to mitigate climate change. Traditional agroforestry is characterized by multifunctionality through the use a variety of native trees to maintain ecological balance and support local livelihoods. This study aimed to determine the plant composition of traditional agroforestry in Rimbo Panjang Village, Kampar, Riau, Indonesia, its utilization, and its role in carbon sequestration. Observations were made in two hamlets, namely Dusun 1 and Dusun 2, where both hamlets have traditional agroforestry systems. Observation on floristic composition was conducted by counting the number of individuals of each species and the diameter at breast height of each individual plant. Carbon sequestration was calculated based on the above-ground biomass determined using an allometric formula accounting for trunk diameter and wood density. The results showed that traditional agroforestry in Dusun 2 had a higher number of plant species, with a total of 17 species, compared to Dusun 1, which had 11 species. The dominant species in Dusun 1 was *Cocos nucifera*, while in Dusun 2 was *Durio zibethinus*. Plants in this agroforestry system have a variety of benefits, both for self-consumption and being marketed for domestic uses and as industrial raw materials. The average carbon sequestration in Rimbo Panjang Village was 508.65 tons/ha CO_2 equivalent (CO_2e), with carbon sequestration in Dusun 2 (618,3 tons/ha CO_2e) higher than that of Dusun 1 (399 tons/ha CO_2e). The high plant diversity in this agroforestry system supports community livelihoods and plays an important role in climate change mitigation through its role in carbon sequestration. These benefits highlight the need to support and develop sustainable agroforestry practices as a sustainable land use strategy, especially in Riau's extensively degraded peatlands.

Keywords: Above-ground biomass, livelihood, Rimbo Panjang, traditional agroforestry, vegetation analysis

INTRODUCTION

Global warming is a significant environmental challenge characterized by a rise in the Earth's surface temperature due to the accumulation of greenhouse gases in the atmosphere. Carbon dioxide (CO_2) is the most prevalent gas and plays an important role in climate change (Mac Dowell et al. 2017). The main causes of increased CO_2 in the atmosphere include burning fossil fuels, deforestation, industrial and modern agricultural activities (Yoro and Daramola 2020; Raihan et al. 2022; Nunes 2023). One promoted strategy to mitigate climate change is by increasing plant uptake of carbon dioxide, which can be achieved through traditional agroforestry systems. Agroforestry is a land management system that integrates trees with crops or pastures to create a more sustainable and productive agricultural system (Alao eand Shuaibu 2013; Raj et al. 2019; Marques et al. 2022). Trees in agroforestry systems contribute to long-term carbon sequestration and help mitigate climate change. Traditional agroforestry is characterized by multifunctionality with the use of native trees to maintain ecological balance and support local livelihoods (Weiwei et al. 2014; Viswanath and Lubina 2017; Worku and Bantihun 2017; Jumiyati and Frimawaty 2024).

Agroforestry systems offer many benefits that contribute to ecological sustainability, economic viability, and community resilience (Sharma et al. 2016; Kassie 2018; Mahmud et al. 2021; Pancholi et al. 2023). Ecological benefits include increased biodiversity, carbon sequestration and improved soil health (Barrios et al. 2018; Mortimer et al. 2018; Nair et al. 2021; Schuler et al. 2022; Eddy and Yang 2022). Agroforestry systems improve soil quality, reduce nutrient leaching, and reduce soil erosion (Sileshi et al. 2020; Zhu et al. 2020; Fahad et al. 2022). The economic benefits of agroforestry include diversified income sources and improved food security (Duffy et al. 2021; Annisa et al. 2021; Viñals et al. 2023; Kittur et al. 2024).

The plants that make up traditional agroforestry play an important role in various aspects of community welfare by providing food, medicinal plants, timber and firewood, generating income, maintaining culture, while sustaining the environment and helping adapt with abiotic and biotic stresses (Mahmud et al. 2021; Widiyanto and Hani 2021; Iskandar et al. 2023; Hiola et al. 2024). There are differences in the number of species, composition, abundance, dominating plant species and their utilization in agroforestry systems in different regions (Kabir and Webb 2008; Todou et al. 2021; Akpalu et al. 2023). Therefore, context-based studies on the floristic composition of plants in traditional agroforestry systems are essential for understanding biodiversity, food security, environmental conservation, cultural practices, adaptation to climate change, and economic benefits.

Agroforestry on peatlands is an efficient terrestrial carbon store and has a key role in climate change mitigation by sequestering carbon from the atmosphere (Harenda et al. 2018; Strobl et al. 2020). Peatlands in Indonesia are quite extensive but most are in degraded condition, including in Riau Province (Anda et al. 2021; Rossita et al. 2023). Peatland degradation results in biodiversity loss, increased greenhouse gas emissions, and increased vulnerability to forest fires (Koivunen et al. 2023). Agroforestry is one of the revegetation efforts to reduce carbon emissions and restore degraded peatlands (Maftu'ah et al. 2021; Jaya et al. 2022).

One of the degraded peatlands in Riau is located in Rimbo Panjang Village, Tambang Sub-district, Kampar District. This village has an extent of 6130 hectares with some areas are located on peatlands (Sudiana 2018; KLHK 2023). Rimbo Panjang Village is one of the areas in Riau Province that develops traditional agroforestry systems on peatlands. This village, located adjacent to Pekanbaru City, cultivates a variety of plants such as rubber, pineapple, areca nut, banana, guava, and cacao (Wirawan 2019). Traditional agroforestry in Rimbo Panjang village is limited in scope, primarily found in the yards of individuals with larger properties, around 500 m^2 in size. In addition, traditional agroforestry management in Rimbo Panjang has been carried out by local communities for generations. Traditional agroforestry is found in Dusun 1 and Dusun 2 of Rimbo Panjang Village.

It is believed that traditional agroforestry established on peatlands has the potential to increase carbon stocks. Yet, such potential is influenced by the the context of biophysical conditions and land management implemented by the farmer which might differ from one region to another. Therefore, this research aimed to investigate the floristic composition of traditional agroforestry systems in Rimbo Panjang Village and understanding the role of each plant species in carbon sequestration. We expected the results of this study might emphasize the importance of biodiversity, increase carbon sequestration, improve peatland management practices, support local economies, and contribute to climate change mitigation efforts.

MATERIALS AND METHODS

Study period and area

This research was conducted from May to June 2024 in Dusun 1 and Dusun 2, Rimbo Panjang Village, Tambang Sub-district, Kampar District, Riau Province, Indonesia (Figure 1). The most common land use systems found in Rimbo Panjang Village are farming rubber, pineapple, areca nut, coconut, cacao plantations, and only a small number of agroforestry systems. Rimbo Panjang has an average monthly rainfall of 270.99 mm, 14 rainy days, an elevation of 28 meters above sea level. Peat depth in the village is between 10 and 244 cm and there are canals with a width of 0.3 to 1.8 meters.

Data collection procedure

Data were collected by purposive sampling, based on traditional agroforestry in Rimbo Panjang Village. Rimbo Panjang Village consists of 3 hamlets, namely Dusun 1, Dusun 2 and Dusun 3. Traditional agroforestry is only found in Dusun 1 and Dusun 2, with a total number of agroforestry in both hamlets only 7 traditional farmers with each farmer generally has area of 500 m^2. We collected data on 6 plots, consisting of 3 plots in the traditional agroforestry system aged 9 years in Dusun 1, and 3 plots in the traditional agroforestry system aged ±15 years in Dusun 2. The plots were 20×20 m or 400 m^2 in size. At each plot, plants that make up the agroforestry were recorded and measurements were made of the circumference of the trunk to obtain data on the diameter at breast height at the level of the trees, poles, and saplings. The wood specific gravity value of each tree refers to the Global Wood Density Database (Siarudin et al. 2021). The tools used in this research are meters, ropes, wooden stakes, cameras, machetes, stationery, and GPS (Global Positioning System).

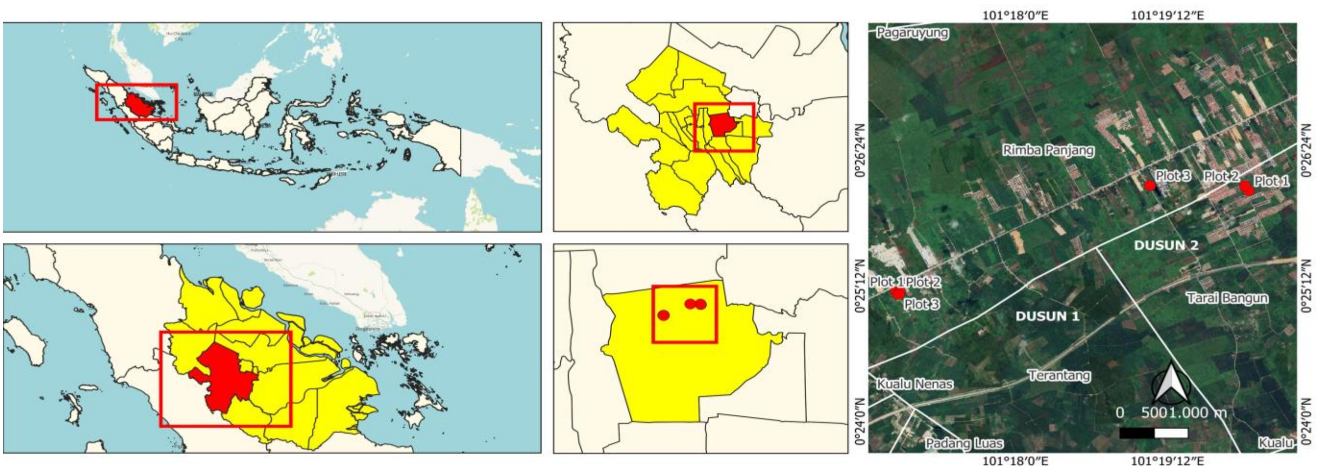

Figure 1. Map of research location in Dusun 1 and Dusun 2, Rimbo Panjang Village, Tambang Sub-district, Kampar District, Riau Province, Indonesia

Research parameters

The parameters of this study included plant species diversity in traditional agroforestry and their utilization, floristic composition, and the contribution of traditional agroforestry plants in sequestering carbon. Floristic composition parameters included density, frequency, dominance, and Importance Value (IV). The contribution of traditional agroforestry plants in sequestering carbon is determined based on the value of carbon sequestration in each plant species, through the calculation of biomass, carbon stock, and carbon sequestration. Tree biomass is determined based on the tree's diameter by measuring the trunk's circumference. Above-ground biomass was determined using an allometric formula based on trunk diameter and wood density. For some plant species for which the allometric formula is already known, the species-specific formula was used. Trees with unknown allometric formulas used the general equation as suggested by Chave et al. (2005):

AGB= p x exp (-0.667+1.784 ln(D)+0.207 (ln(D))2-0.0281 $(\ln(D))^3$)

Where:
AGB: Above Ground Biomass
exp: exponential
p: Specific gravity of wood (g/cm^3) based on the Global Wood Density Database (Siarudin et al. 2021)
D: Tree diameter (cm)

Palm species (coconut, areca nut, oil palm), biomass was analyzed using Brown's (1997) allometric formula, viz:

AGB= exp(-2.134+2.530 x ln(D))

The calculation of carbon stock using the formula:
Carbon stock= B x % organic C
Where:
B: Biomass (tons)

% organic C: Percentage of carbon content (0.47) (SNI 2011)

Calculation of carbon sequestration equivalent (CO_2e) used the formula as follow:
Carbon sequestration equivalent = Carbon Stock x 3.67
Where:
3.67: Conversion from C to CO_2

Data analysis

Data of the composition of plants and their utilization were analyzed descriptively based on the values in the table. Floristic composition data were analyzed based on the Important Value Index through calculations using software Microsoft Excel. Data on the contribution of agroforestry constituent plants in sequestering carbon were analyzed descriptively based on percentage data for each sequestering carbon agroforestry constituent plant species.

RESULTS AND DISCUSSION

Diversity and uses of plant species in traditional agroforestry in Rimbo Panjang Village, Kampar, Riau

There are differences in the number of species, species composition, and density of plants that make up traditional agroforestry in Dusun 1 and Dusun 2 (Table 1). Dusun 1 had 1,275 ind/ha of constituent plants, consisting of 11 species from 8 different families. The constituent plants of traditional agroforestry in Dusun 2 were 1,825 ind/ha, consisting of 17 species from 12 families, suggesting higher diversity compared to Dusun 1. The most common species found in Dusun 1 was areca nut (*Areca catechu*) with 475 ind/ha, other species were coconut (*Cocos nucifera*) and jackfruit (*Artocarpus heterophyllus*) with 200 ind/ha and 125 ind/ha, respectively. The most common species found in Dusun 2 was water guava (*Syzygium aqueum*) at 425 ind/ha, other species were durian (*Durio zibethinus*) and cacao (*Theobroma cacao*) which were also quite dominant at 325 ind/ha. Arecaceae and Sapindaceae the dominant families in Dusun 1, while in Dusun 2 it was dominated by Malvaceae and Arecaceae.

The plants that constitute traditional agroforestry in Rimbo Panjang are generally used for self-consumption, with only a few of them being marketed (Table 2). Some of those marketed are generally classified as plants that are widely found in Dusun 1 and Dusun 2, such as areca nut, palm oil, jackfruit, durian, and water guava. The plants primarily used for personal consumption are generally less abundant. Most of the plants in the agroforestry system in Rimbo Panjang are utilized for their fruits, some as ingredients or spices, and as raw materials for various industries. Marketed crops are usually used as industrial materials, for example, areca nut, cacao, and palm oil. Some of the plants that constitute traditional agroforestry in Dusun 1 and Dusun 2 are shown in Figure 2.

Plants found in Dusun 1 include areca nut, coconut, and jackfruit. Areca nut plants are highly favored by the community due to their significant economic value, ease of maintenance, and market demand. Typically, marketing involves collaboration with middlemen who process the plant's products. Additionally, areca nut plants can be intercropped with other species such as fruit and food crops, providing potential income for the community, especially through the production of areca nut oil used in the cosmetic, pharmaceutical, and food industries (Guo et al. 2024). Rubber is not marketed due to the small number of trees. Coconut and jackfruit also have economic value for the community, serving both personal consumption and market sales. The traditional agroforestry practice, known as the yard system, is commonly employed on the cultivation of these fruit plants (Hartoyo et al. 2022).

Table 1. List of plant in traditional agroforestry in Rimbo Panjang Village, Kampar District, Riau, Indonesia

Location	Species	Family	English name	Number of indiv/plot	Number of indiv/ha
Dusun 1	*Areca catechu* L.	Arecaceae	Areca nut	19	475
	Cocos nucifera L.	Arecaceae	Coconut	8	200
	Hevea brasiliensis (Willd. ex A.Juss.) Müll.Arg.	Euphorbiaceae	Rubber	5	125
	Artocarpus heterophyllus Lam.	Moraceae	Jackfruit	5	125
	Durio zibethinus Murray	Malvaceae	Durian	4	100
	Musa paradisiaca L.	Musaceae	Banana	4	100
	Nephelium lappaceum L.	Sapindaceae	Rambutan	2	50
	Litchi chinensis Sonn.	Sapindaceae	Longan	1	25
	Pometia pinnata J.R.Forst. & G.Forst.	Sapindaceae	Matoa	1	25
	Mangifera indica L.	Anacardiaceae	Mango	1	25
	Syzygium polyanthum (Wight) Walp.	Myrtaceae	Bay leaf	1	25
Total				51	1275
Dusun 2	*Syzygium aqueum* (Burm.fil.) Alston	Myrtaceae	Water Guava	17	425
	Durio zibethinus Murray	Malvaceae	Durian	13	325
	Theobroma cacao L.	Malvaceae	Cocoa	13	325
	Areca catechu L.	Arecaceae	Areca nut	7	175
	Musa paradisiaca L.	Musaceae	Banana	5	125
	Elaeis guineensis Jacq.	Arecaceae	Palm oil	3	75
	Cocos nucifera L.	Arecaceae	Coconut	2	50
	Archidendron pauciflorum (Benth.) I.C.Nielsen	Fabaceae	Jengkol	2	50
	Garcinia mangostana L.	Clusiaceae	Mangosteen	2	50
	Artocarpus heterophyllus Lam.	Moraceae	Jackfruit	2	50
	Averrhoa bilimbi L.	Oxalidaceae	Starfruit	1	25
	Citrus aurantifolia (Christm.) Swingle	Rutaceae	Lime	1	25
	Terminalia catappa L.	Combretaceae	Ketapang	1	25
	Mangifera indica L.	Anacardiaceae	Mango	1	25
	Artocarpus altilis Lam.	Moraceae	Sukun	1	25
	Nephelium lappaceum L.	Sapindaceae	Rambutan	1	25
	Manilkara zapota (L.) P.Royen	Sapotaceae	Sawo	1	25
Total				73	1825

Table 2. Use of plants that compose traditional agroforestry in Rimbo Panjang Village, Kampar District, Riau, Indonesia

Location	English name	Uses	Marketed/self-consumption
Dusun 1	Areca nut	Industrial raw materials	Marketed
	Coconut	Cooking ingredients	Marketed
	Rubber	Industrial raw materials	-
	Jackfruit	Fruit	Marketed
	Durian	Fruit	Marketed
	Banana	Fruit	Marketed
	Rambutan	Fruit	Self-consumption
	Longan	Fruit	Self-consumption
	Matoa	Fruit	Self-consumption
	Mango	Fruit	Self-consumption
	Bay leaf	Cooking ingredients	Sself-consumption
Dusun 2	Water Guava	Fruit	Marketed
	Durian	Fruit	Marketed
	Cocoa	Industrial raw materials	Marketed
	Areca nut	Industrial raw materials	Marketed
	Banana	Fruit	Marketed
	Palm oil	Industrial raw materials	Marketed
	Coconut	Cooking ingredients	Marketed
	Jengkol	Cooking ingredients	Self-consumption
	Mangosteen	Fruit	Self-consumption
	Jackfruit	Fruit	Marketed
	Starfruit	Cooking ingredients	Self-consumption
	Lime	Fruit	Self-consumption
	Ketapang	Shade tree	-
	Mango	Fruit	Self-consumption
	Sukun	Fruit	Self-consumption
	Rambutan	Fruit	Self-consumption
	Sawo	Fruit	Self-consumption

Figure 2. Plants that compose traditional agroforestry in Rimbo Panjang, Kampar District, Riau, Indonesia: A. Dusun 1, B. Dusun 2.

Water guava, durian, and cocoa are commonly found in Dusun 2. These plants are planted for their delightful taste, and are privately consumed as well as have a high demand from buyers, thereby contributing to increase community income**.** According to a study Mardhiansyah et al. (2022), the agroforestry system on peatlands in Riau applies a random planting pattern of several plants such as coconut, areca nut, palm oil with other types of woody plants. The high diversity of plants that make up agroforestry is expected to be able to meet the daily needs of the community.

The palm group typically dominates in Dusun 1 and Dusun 2, while other species including longan, *matoa*, mango, *salam*, *belimbing wuluh*, lime, *ketapang*, breadfruit, *rambutan*, and *sawo*, which were found in limited quantities (25 ind/ha). Palms are easier to grow on the peatlands that dominate in Rimbo Panjang. Several species are the same between Dusun 1 and Dusun 2 such as durian, coconut, mango, areca nut, banana, and jackfruit. Other research conducted by Samosir et al. (2021) on traditional agroforestry systems in North Sumatra showed that plants that are commonly found in traditional agroforestry systems are generally fruit plants such as bananas, jackfruit, durian, *jengkol*, and mangoes. According to Kasi et al. (2024), durian is the most planted crop in traditional agroforestry systems, followed by coconut, cacao, mangosteen, and guava. Additionally, fruit plants produce flowers that attract pollinating animals, providing ecological benefits (Hartoyo et al. 2022).

Important value index of plant in traditional agroforestry in Rimbo Panjang Village, Kampar, Riau

The important value index represents plants that dominate based on the value of relative density, relative frequency, and relative dominance. The results of the important value index of the plants that compose traditional agroforestry in Rimbo Panjang are presented in Tables 3 and 4. The most dominant tree species in Dusun 1 is *C. nucifera*, followed by *Hevea brasiliensis*, *Syzygium polyanthum*, and the lowest importance value is *Mangifera indica*. The pole and sapling levels are dominated by *A. catechu*. Tree species in Dusun 2 are dominated by *D. zibethinus*, followed by *Elaeis guineensis*, *Archidendron pauciflorum*, and the lowest are several species, namely *Nephelium lappaceum*, *Artocarpus altilis*, *Musa paradisiaca*. The pole level is dominated by *A. catechu*, while the sapling level is dominated by *S. aqueum*.

Table 3. Relative density, relative frequency, relative dominance, and importance value index plants in traditional agroforestry in Dusun 1, Rimbo Panjang Village, Kampar District, Riau, Indonesia

Species	RD (%)	RF (%)	RDo (%)	IVI (%)
Tree				
Cocos nucifera	61.54	33.33	58.55	153.42
Hevea brasiliensis	15.38	16.67	16.45	48.49
Syzygium polyanthum	7.69	16.67	13.97	38.32
Nephelium lappaceum	7.69	16.67	6.77	31.13
Mangifera indica	7.69	16.67	4.26	28.62
Pole				
Areca catechu	78.57	39.99	68.35	186.92
Pometia pinnata	7.14	19.99	15.11	42.26
Hevea brasiliensis	7.14	19.99	9.59	36.73
Musa paradisiaca	7.14	19.99	6.95	34.09
Sapling				
Areca catechu	33.33	20.00	43.54	96.87
Musa paradisiaca	12.50	20.00	20.61	53.11
Durio zibethinus	16.67	10.00	18.19	44.86
Artocarpus heterophyllus	20.83	10.00	7.29	38.13
Hevea brasiliensis	8.33	20.00	6.30	34.64
Nephelium lappaceum	4.17	10.00	3.25	17.42
Litchi chinensis	4.17	10.00	0.81	14.98

Note: RD: Relative Density, RF: Relative Frequency, RDo: Relative Dominance, IVI: Importance Value Index

Table 4. Relative density, relative frequency, relative dominance and importance value of traditional agroforestry vegetation in Dusun 2, Rimbo Panjang Village, Kampar District, Riau, Indonesia

Species	RD (%)	RF (%)	RDo (%)	IVI (%)
Tree				
Durio zibethinus	35.29	25.00	22.26	82.55
Elaeis guineensis	17.64	8.33	45.27	71.22
Archidendron pauciflorum	11.76	16.67	9.99	38.42
Terminalia catappa	5.88	8.33	5.71	19.92
Cocos nucifera	5.88	8.33	4.29	18.51
Artocarpus heterophyllus	5.88	8.33	3.34	17.56
Artocarpus altilis	5.88	8.33	3.25	17.47
Musa paradisiaca	5.88	8.33	3.081	17.29
Nephelium lappaceum	5.88	8.33	2.83	17.04
Pole				
Areca catechu	29.16	8.33	26.64	64.14
Musa paradisiaca	16.66	16.67	17.39	50.72
Syzygium aqueum	16.66	16.67	10.31	43.64
Mangifera indica	4.17	8.33	8.053	20.55
Cocos nucifera	4.17	8.33	7.29	19.79
Theobroma cacao	4.17	8.33	4.39	16.88
Artocarpus heterophyllus	4.17	8.33	2.71	15.21
Garcinia mangostana	4.16	8.33	2.28	14.78
Durio zibethinus	16.67	16.67	20.94	5.27
Sapling				
Syzygium aqueum	40.63	25.00	38.21	109.37
Theobroma cacao	37.50	16.67	37.80	88.59
Durio zibethinus	9.375	25.00	10.89	44.30
Citrus aurantifolia	3.125	8.33	4.52	15.58
Manilkara zapota	3.125	8.33	3.50	14.65
Averrhoa bilimbi	3.125	8.33	3.19	14.36
Garcinia mangostana	3.125	8.33	1.853	13.14

Note: RD: Relative Density, RF: Relative Frequency, RDo: Relative Dominance, IVI: Importance Value Index

The dominant plants in the traditional agroforestry system of Rimbo Panjang Village are planted in larger quantities because they are easy to market, thus increasing community income. *Cocos nucifera* is planted because it is easy to market and can be consumed by itself as a cooking ingredient. *Areca catechu* is planted because it is easy to market, as an industrial raw material. Some plants with high importance index include fruit-producing plants that can be consumed and marketed, such as *D. zibethinus, M. paradisiaca*, and *S. aqueum*.

The results of the vegetation analysis of the plants that make up the traditional agroforestry system in Rimbo Panjang Village show that the dominating plants for the tree, pole, and sapling levels include *C. nucifera, A. catechu, D. zibethinus*, and *S. aqueum*. There are differences and similarities in the constituent and dominating plants in different traditional agroforestry systems in different regions. Traditional agroforestry in Mamar, Kupang, Indonesia is dominated by several tree and pole species including *Gmelina arborea, Syzygium pycnanthum, Swietenia mahagoni, A. catechu*, and *Borassus flabellifer*. *Areca catechu* is a dominant species in several locations in Mamar, Kupang (Ngaji et al. 2021). The dominant species in traditional agroforestry in Berau, East Kalimantan is also areca nut (*A. catechu*) (Hartoyo et al. 2016). Agroforestry systems in Kinnaur, North-western Himalayas, India are dominated by *Malus domestica* (Apple) (Salve et al. 2018). Plants abundant in traditional agroforestry in Habro District, Oromia State, Ethiopia include *Catha edulis, Coffea arabica*, and *Cordia africana* (Dekeba et al. 2019).

The high biodiversity of plants that make up traditional agroforestry in Rimbo Panjang is indicated by a fairly high number of species, of which Dusun 1 has 11 species and Dusun 2 consists of 17 species. This high plant biodiversity also provides diverse benefits for the community, namely as fruit-producing plants, cooking spices, industrial raw materials and shade plants. This is a source of livelihood for the community, both as additional income and for their own needs which can reduce the cost of daily living. Generally, traditional agroforestry in different regions shows high plant biodiversity, for example, across 540 traditional agroforestry plots in south-central Ethiopia, 138 perennial plant species were found (Tadesse et al. 2021). The high plant biodiversity of the 23 traditional agroforestry homegardens of Harapan Makmur Village, Bengkulu, Indonesia showed a wide range of utilization, with 41 species for food, 21 species for firewood, 13 species for ornamental plants, 11 species for medicine, 7 species for building wood, 6 species for shade trees, 4 species for fences, 3 species for fodder, 2 species for handicrafts, and 2 species for dyes (Wiryono et al. 2016). Three ethnic communities in Central Sulawesi, Indonesia utilize plants from traditional agroforestry, of which the Tao Taa Wana community utilizes 43 species, the Javanese community utilizes 52 species and the Mentawa community utilizes 39 species. The plants are used for a variety of uses, including medicine, food, natural dyes, fuel, building materials, decoration, and traditional ritual (Pitopang et al. 2021).

Contribution of agroforestry plants to carbon sequestration

The plants that constitute agroforestry also play a crucial role in carbon sequestration, which is important in mitigating climate change. The contribution of plants that make up traditional agroforestry in Dusun 1 and Dusun 2 in absorbing carbon can be seen in Table 5. Likewise, traditional agroforestry in Dusun 1 and Dusun 1 in Table 5 shows that there are various types of plants that each have different contributions to the absorption of carbon dioxide (CO_2) from the atmosphere.

The highest proportion of plants in absorbing carbon in Dusun 1 is coconut (40.88%) followed by banana (27.02%), bay tree (11.11%), areca nut (9.88%), and rambutan (5.64%), mango (2.25%), *matoa* (1.94%), durian (0.88%), jackfruit (0.32%), rubber (0.06%), and the lowest is longan (0.02%). There are differences in the types of plants that are highest in absorbing carbon in traditional agroforestry in Dusun 1 and Dusun 2. The highest plant in absorbing carbon in Dusun 2 is palm oil (52.2%), followed by durian (19.1%), *jengkol* (6.9%), water guava (4.5%), and areca nut (4.3%). Several other plants in Dusun 2 showed a low proportion in absorbing carbon with the proportion of absorbing carbon being *ketapang* (2.9%), *rambutan* (2.5%), jackfruit (2.4%), breadfruit (2.1%), mango (1.4%), cacao (0.6%), banana (0.4%), mangosteen (0.3%), and the lowest were star fruit, lime and sapodilla (0.1%). These different contributions are also caused by differences in the number of individuals of each constituent species in Dusun 1 and Dusun 2 which can be seen in the previous Tables 1, 4, and 5, as well as based on stem diameter and wood density.

The oil palms in Dusun 2 are actually only a few (3 individuals/plot), with oil palms over 18 years old with very large stem diameters which result in high biomass, as well as carbon stocks and carbon sequestration. However, other plants such as durian and guava, despite their high density and fruiting, are still young and have very small trunk diameters. Therefore, even though oil palm is not the main plant in this study site, it contributes the highest carbon sequestration due to its older age and high stem diameter. Although oil palm is the main cause of peatland degradation in Riau and other areas, it cannot be eliminated due to its high economic value and high market demand. Therefore, one alternative for sustainable land use, including degraded peatlands, is oil palm-based agroforestry systems. Various crops can be associated in oil palm agroforestry systems, such as fruit-bearing food plants, cereals, tubers, nuts, woody plants and ground cover plants. These associations increase biodiversity and ecosystem services (Masure et al. 2023).

Table 5. Contribution of traditional agroforestry plants in Rimbo Panjang Village, Kampar District, Riau, Indonesia in carbon sequestration

Location	English name	Biomass (ton/ha)	Carbon stock (ton/ha)	Carbon sequestration (ton/ha)	Proportion (%)
Dusun 1	Coconut	94.56	44.44	163.10	40.88
	Banana	62.50	29.38	107.81	27.02
	Bay leaf	25.69	12.08	44.32	11.11
	Areca nut	22.85	10.74	39.41	9.88
	Rambutan	13.04	6.13	22.49	5.64
	Mango	5.22	2.45	9.00	2.25
	Matoa	4.49	2.11	7.75	1.94
	Durian	2.03	0.95	3.50	0.88
	Jackfruit	0.75	0.35	1.29	0.32
	Rubber	0.14	0.07	0.24	0.06
	Longan	0.05	0.02	0,09	0.02
Total		231.32	108.72	399	100
Dusun 2	Oil palm	186.85	87.82	322.3	52.2
	Durian	68.35	32.13	117.9	19.1
	Jengkol	24.87	11.69	42.9	6.9
	Water Guava	16.12	7.57	27.8	4.5
	Areca nut	15.31	7.19	26.4	4.3
	Ketapang	10.32	4.85	17.8	2.9
	Rambutan	9.10	4.28	15.7	2.5
	Jackfruit	8.75	4.11	15.1	2.4
	Breadfruit	7.94	3.73	13.7	2.1
	Mango	5.04	2.37	8.7	1.4
	Kakao	2.15	1.01	3.7	0.6
	Banana	1.51	0.71	2.6	0.4
	Mangosteen	0.93	0.44	1,6	0.3
	Starfruit	0.46	0.22	0.8	0.1
	Lime	0.41	0.19	0.7	0.1
	Sawo	0.35	0.16	0.6	0.1
Total		358.40	168.45	618,3	100
Average		294.86	138.585	508.65	

The total biomass in the traditional agroforestry system of Dusun 2 (358.40 tons/ha) was higher than that of Dusun 1 (231.32 tons/ha). Biomass values, carbon stocks, and carbon sequestration in the agroforestry system of Rimbo Panjang Village were 294.86, 138.585, and 508.6 tons/ha, respectively. Based on the results of this study we can be concluded that traditional agroforestry in both hamlets has the potential to reduce carbon dioxide emissions through sequestering and accumulating in the form of vegetation biomassd.

Therefore, it is important to preserve and develop traditional agroforestry as one of the strategies to address climate change and strengthen environmental resilience at the local level. Besides its importance in carbon sequestration, agroforestry also provides a variety of other ecological and economic benefits. Trees in agroforestry systems provide benefits as fruit, shade and firewood producers, building materials (Okullo et al. 2003; Sibelet et al. 2019; Kuyah et al. 2020; Lelamo 2021), improve soil fertility, prevent erosion (Pinho et al. 2012; Masebo and Menamo 2016; Kaushal et al. 2021; Lelamo 2021; Fahad et al. 2022) and biodiversity conservation (Udawatta et al. 2021). Traditional agroforestry systems are sustainable land-use systems with higher plant diversity that support a diversity of fauna, and soil microbes that are important for soil health (Jose 2012; Marsden et al. 2020; Udawatta et al. 2019, et al. 2021).

The carbon stock values and carbon sequestration in various agroforestry systems showed different values. In East Kalimantan, Indonesia, traditional agroforestry in Birang Village demonstrated the highest carbon stock value at 205.22 tons/ha, followed by Merabu Village at 178.63 tons/ha, and the traditional zone of Mount Halimun Salak National Park (MHSNP) at 108.55 tons/ha (Hartoyo et al. 2022). In the agroforestry of the Eastern Himalayan Region of India, differences in carbon stocks are evident, with approximately 4.72 tons/ha in Meitei and 29.26 tons/ha in Bengal (Nath et al. 2022). Furthermore, the agroforestry system in the Sahelo-Sudan region exhibited an average carbon stock value of 43.42 tons/ha, while the silvopastoral system in the Iran region had a carbon stock value of 36.33 (Sambou et al. 2024). These variations in carbon stock and carbon sequestration values are attributed to the composition of constituent plant species and overall stand structure, encompassing tree density, mean diameter, and basal area (Hartoyo et al. 2022; Sambou et al. 2024).

The diversity of plants that constitute traditional agroforestry in Rimbo Panjang, Kampar, Riau shows a number of economic and environmental benefits. Plants in this agroforestry system have a number of uses, including industrial raw materials, cooking ingredients and fruits that support market-oriented production and local food needs. The various plant species that make up this agroforestry also show high potential in carbon sequestration, which is important in mitigating climate change. Therefore, it is necessary to support and develop sustainable agroforestry practices as a sustainable land use strategy, especially in the vast degraded peatlands in Riau.

In conclusion, traditional agroforestry offers many benefits that contribute to environmental sustainability, economic viability and community resilience. The results showed that traditional agroforestry in Dusun 2 had a higher number of plant species, with a total of 17 species from 12 families, compared to Dusun 1, which had 11 species from 8 families. There are differences in plants that dominate in both dusun, where for tree, pole and sapling levels in Dusun 1 each dominated by *C. nucifera* and *A. catechu*, while in Dusun 2 dominated by *D. zibethinus*, *A. catechu* and *S. aqueum*. Plants in this agroforestry system have multiple benefits, both for self-consumption and being marketed for domestic uses or industrial raw materials. This diversity highlighted the multifunctionality of agroforestry, which supports market-oriented production and local food needs. The plants that contributed the most carbon sequestration were coconut and banana in Dusun 1 and oil palm and durian in Dusun 2. The average carbon sequestration in Rimbo Panjang Village was 508.65 tons/ha, with carbon sequestration in agroforestry of Dusun 2 (618.3 tons/ha) higher than in Dusun 1 (399 tons/ha). The findings from this study highlight the importance of traditional agroforestry systems in promoting biodiversity and enhancing carbon sequestration. The high plant biodiversity of agroforestry in Rimbo Panjang not only supports local livelihoods, but also plays an important role in climate change mitigation efforts by serving as a significant carbon sink. These benefits highlight the need to support and develop sustainable agroforestry practices as a sustainable land use strategy, especially in Riau's extensive degraded peatlands.

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REFERENCES

Akpalu SE, Anglaaere L, Damnyag L, Dawoe EK, Abunyewa AA, Akpalu MM. 2023. Floristic composition of agroforestry parklands in the semi-arid zone of Ghana: A special focus on *Faidherbia albida* (Delile) A. Chev. Trees For People 9: 100310. DOI: 10.1016/j.tfp.2022.100310.

Alao JS, Shuaibu RB. 2013. Agroforestry practices and concepts in sustainable land use systems in Nigeria. J Hortic For 5 (10): 156-159. DOI: 10.5897/JHF11.055.

Anda M, Ritung S, Suryani E, Hikmat M, Yatno E, Mulyani A, Subandiono RE, Suratman, Husnain. 2021. Revisiting tropical peatlands in Indonesia: Semi-detailed mapping, extent and depth distribution assessment. Geoderma 402: 115235. DOI: 10.1016/j.geoderma.2021.115235.

Annisa W, Susilawati A, Fahmi A, Nursyamsi D. 2021. Potential of agroforestry system on peat land to enhance food security and environmental sustainability. E3S Web Conf 305: 05005. DOI: 10.1051/e3sconf/202130505005.

Barrios E, Valencia V, Jonsson M, Brauman A, Hairiah K, Mortimer PE, Okubo S. 2018. Contribution of trees to the conservation of biodiversity and ecosystem services in agricultural landscapes. Intl J Biodivers Sci Ecosyst Serv Manag 14 (1): 1-16. DOI: 10.1080/21513732.2017.1399167.

Brown S. 1997. Estimating Biomass and Biomass Change of Tropical Forests: A Primer. FAO Forestry Paper, Rome.
Chave J, Andalo C, Brown S, Cairns MA, Chambers JQ, Eamus D, Fölster H, Fromard F, Higuchi N, Kira T. 2005. Tree allometry and improved estimation of carbon stocks and balance in tropical forests. Oecologia 145: 87-99. DOI: 10.1007/s00442-005-0100-x.
Dekeba S, Nigatu L, Mohammed M. 2019. Floristic composition of homegarden agroforestry system in Habro District, Oromia Regional State, Ethiopia. Oct J Environ Res 7 (3): 74-86.
Duffy C, Toth GG, Hagan RP, McKeown PC, Rahman SA, Widyaningsih Y, Sunderland TC, Spillane C. 2021. Agroforestry contributions to smallholder farmer food security in Indonesia. Agrofor Syst 95 (6): 1109-1124. DOI: 10.1007/s10457-021-00632-8.
Eddy WC, Yang WH. 2022. Improvements in soil health and soil carbon sequestration by an agroforestry for food production system. Agric Ecosyst Environ 333: 107945. DOI: 10.1016/j.agee.2022.107945.
Fahad S, Chavan SB, Chichaghare AR et al. 2022. Agroforestry systems for soil health improvement and maintenance. Sustainability 14 (22): 14877. DOI: 10.3390/su142214877.
Guo Z, Wang Z, Luo Y, Ma L, Hu X, Chen F, Li D, Jia M. 2024. Extraction and identification of bioactive compounds from areca nut (*Areca catechu* L.) and potential for future applications. Food Front 5 (5): 1909-1932. DOI: 10.1002/fft2.443.
Harenda KM, Lamentowicz M, Samson M, Chojnicki BH. 2018. The role of peatlands and their carbon storage function in the context of climate change. In: Zielinski T, Sagan I, Surosz W (eds). Interdisciplinary Approaches for Sustainable Development Goals: Economic Growth, Social Inclusion and Environmental Protection. Springer, Cham. DOI: 10.1007/978-3-319-71788-3_12.
Hartoyo AP, Khairunnisa S, Pamoengkas P, Solikhin A, Siregar IZ, Prasetyo LB. 2022. Estimating carbon stocks of three traditional agroforestry systems and their relationships with tree diversity and stand density. Biodiversitas 23 (12): 6137-6146. DOI: 10.13057/biodiv/d231207.
Hartoyo AP, Siregar IZ, Prasetyo LB, Thelaide I. 2016. Biodiversity, carbon stocks and community monitoring in traditional agroforestry practices: Preliminary results from two investigated villages in Berau, East Kalimantan. Procedia Environ Sci 33: 376-385. DOI: 10.1016/j.proenv.2016.03.088.
Hiola AS, Soemarno, Cahyono ED, Prayogo C. 2024. The traditional agroforestry system and community welfare: Evidence from Dulamayo, Indonesia. Univ J Agric Res 12 (1): 96-107. DOI: 10.13189/ujar.2024.120110.
Iskandar BS, Suryana Y, Mulyanto D, Iskandar J, Gunawan R. 2023. Ethnomedicinal aspects of Sundanese traditional homegarden: A case study in rural Sumedang, West Java, Indonesia. J Trop Ethnobiol 6 (1): 57-78. DOI: 10.46359/jte.v6i1.167.
Jaya A, Elia A, Antang EU, Octora M, Ichriani GI, Dohong S, Sulistiyanto Y. 2022. A study of agroforestry farming for tropical peatland conservation and rehabilitation in Central Kalimantan, Indonesia. Mires Peat 28 (22): 1-34. DOI: 10.19189/MaP.2021.OMB.StA.2368.
Jose S. 2012. Agroforestry for conserving and enhancing biodiversity. Agrofor Syst 85: 1-8. DOI: 10.1007/s10457-012-9517-5.
Jumiyati S, Frimawaty E. 2024. Application of edu-agrotourism and agroforestry: Patterns of land use on conservation in the buffer area. Intl J Conserv Sci 15 (1): 657-672. DOI: 10.36868/IJCS.2024.01.19.
Kabir ME, Webb EL. 2008. Floristics and structure of southwestern Bangladesh homegardens. Intl J Biodivers Sci Manag 4 (1): 54-64. DOI: 10.1080/17451590809618183.
Kasi NS, Ohorella S, Irnawati. 2024. Struktur dan komposisi serta profil agroforestri tradisional di Kampung Teluk Dore Kabupaten Sorong. Jurnal Ilmu Pertanian dan Kehutanan 2: 11-20. [Indonesian]
Kassie GW. 2018. Agroforestry and farm income diversification: Synergy or trade-off? The case of Ethiopia. Environ Syst Res 6: 8. DOI: 10.1186/s40068-017-0085-6.
Kaushal R, Mandal D, Panwar P, Kumar P, Tomar JM, Mehta H. 2021. Soil and water conservation benefits of agroforestry. In: Shit PK, Pourghasemi HR, Adhikary PP, Bhunia GS, Sati VP (eds). Forest Resources Resilience and Conflicts. Elsevier, Amsterdam. DOI: 10.1016/B978-0-12-822931-6.00020-4.
Kementerian Lingkungan Hidup dan Kehutanan (KLHK). 2023. Peta Tutupan Lahan. Kementerian Lingkungan Hidup dan Kehutanan, Jakarta. [Indonesian]
Kittur BH, Upadhyay AP, Jhariya MK, Raj A, Banerjee A. 2024. Agroforestry for resource diversification and sustainable development. In: Jhariya MK, Meena RS, Banerjee A, Kumar S, Raj A (eds). Agroforestry for Carbon and Ecosystem Management. Academic Press, London. DOI: 10.1016/B978-0-323-95393-1.00028-2.
Koivunen I, Muotka T, Jokikokko M, Virtanen R, Jyväsjärvi J. 2023. Downstream impacts of peatland drainage on headwater stream biodiversity and ecosystem functioning. For Ecol Manag 543: 121143. DOI: 10.1016/j.foreco.2023.121143.
Kuyah S, Sileshi GW, Luedeling E, Akinnifesi FK, Whitney CW, Bayala J, Kuntashula E, Dimobe K, Mafongoya PL. 2020. Potential of agroforestry to enhance livelihood security in Africa. In: Dagar JC, Gupta SR, Teketay D (eds). Agroforestry for Degraded Landscapes: Recent Advances and Emerging Challenges. Springer, Singapore. DOI: 10.1007/978-981-15-4136-0_4.
Lelamo LL. 2021. Review on the indigenous multipurpose agroforestry tree species in Ethiopia: Management, their productive and service roles and constraints. Heliyon 7 (9): e07874. DOI: 10.1016/j.heliyon.2021.e07874.
Mac Dowell N, Fennell PS, Shah N, Maitland GC. 2017. The role of CO_2 capture and utilization in mitigating climate change. Nat Clim Chang 7 (4): 243-249. DOI: 10.1038/nclimate3231.
Maftu'ah E, Susilawati A, Sulaeman Y. 2021. Agroforestry for restoration of degraded peatlands. E3S Web Conf 305: 03001. DOI: 10.1051/e3sconf/202130503001.
Mahmud AA, Raj A, Jhariya MK. 2021. Agroforestry systems in the tropics: A critical review. Intl J Agric Biol Res 37 (1): 83-87. DOI: 10.35248/0970-1907.21.37.83-87.
Mardhiansyah M, Asyari TA, Darlis VV, Mursyid H. 2022. Persepsi masyarakat terhadap agroforestri pada lahan gambut di Provinsi Riau. J For Sci Avicennia 5 (2): 151-158. DOI: 10.22219/avicennia.v5i2.22124. [Indonesian]
Marques MA, Anjos LH, Delgado ARS. 2022. Land recovery and soil management with agroforestry systems. Span J Soil Sci 19 (12): 10457. DOI: 10.3389/sjss.2022.10457.
Marsden C, Martin-Chave A, Cortet J, Hedde M, Capowiez Y. 2020. How agroforestry systems influence soil fauna and their functions-a review. Plant Soil 453: 29-44. DOI: 10.1007/s11104-019-04322-4.
Masebo N, Menamo M. 2016. A review paper on: The role of agroforestry for rehabilitation of degraded soil. J Biol Agric Healthc 6 (5): 128-135.
Masure A, Martin P, Lacan X, Rafflegeau S. 2023. Promoting oil palm-based agroforestry systems: An asset for the sustainability of the sector. Cah Agric 32: 16. DOI: 10.1051/cagri/2023008.
Mortimer R, Saj S, David C. 2018. Supporting and regulating ecosystem services in cacao agroforestry systems. Agrofor Syst 92 (6): 1639-1657. DOI: 10.1007/s10457-017-0113-6.
Nair PR, Kumar BM, Nair VD, Nair PR, Kumar BM, Nair VD. 2021. Agroforestry for Biodiversity Conservation. An Introduction to Agroforestry: Four Decades of Scientific Developments. Springer, Cham. DOI: 10.1007/978-3-030-75358-0.
Nath PC, Thangjam U, Kalita SS, Sahoo UK, Giri K, Nath AJ. 2022. Tree diversity and carbon important species vary with traditional agroforestry managers in the Indian Eastern Himalayan region. Environ Sci Pollut Res 29 (43): 64732-64744. DOI: 10.1007/s11356-022-20329-4.
Ngaji AU, Baiquni M, Suryatmojo H, Haryono E. 2021. Assessing the sustainability of traditional agroforestry practices: A case of mamar agroforestry in kupang-indonesia. For Soc 5 (2): 438-457. DOI: 10.24259/fs.v5i2.14380.
Nunes LJ. 2023. The rising threat of atmospheric CO_2: A review on the causes, impacts, and mitigation strategies. Environments 10 (4): 66. DOI: 10.3390/environments10040066.
Okullo JB, Obua J, Kaboggoza JR, Aluma JR. 2003. Traditional agroforestry systems, tree uses and management in northern Uganda. Uganda J Agric Sci 2003 (8): 5-12.
Pancholi R, Yadav R, Gupta H, Vasure N, Choudhary S, Singh MN, Rastogi M. 2023. The role of agroforestry systems in enhancing climate resilience and sustainability-A review. Intl J Environ Clim Chang 13 (11): 4342-4353. DOI: 10.9734/ijecc/2023/v13i113615.
Pinho RC, Miller RP, Alfaia SS. 2012. Agroforestry and the improvement of soil fertility: A view from Amazonia. Appl Environ Soil Sci 2012: 616383. DOI: 10.1155/2012/616383.
Pitopang R, Atmoko AT, Mertosono SR, Ramawangsa PA. 2021. Plant diversity in agroforestry system and its traditional use by three different ethnics in Central Sulawesi Indonesia. IOP Conf Ser: Earth

Environ Sci 886 (1): 012058. DOI: 10.1088/1755-1315/886/1/012058.
Raihan A, Begum RA, Nizam M, Said M, Pereira JJ. 2022. Dynamic impacts of energy use, agricultural land expansion, and deforestation on CO_2 emissions in Malaysia. Environ Ecol Stat 29 (3): 477-507. DOI: 10.1007/s10651-022-00532-9.
Raj A, Jhariya MK, Yadav DK, Banerjee A, Meena RS. 2019. Agroforestry: A holistic approach for agricultural sustainability. In: Jhariya MK, Banerjee A, Meena RS, Yadav DK (eds). Sustainable Agriculture, Forest and Environmental Management. Springer, Singapore. DOI: 10.1007/978-981-13-6830-1_4.
Rossita A, Boer R, Hein L, Nurrochmat D, Riqqi A. 2023. Peatland fire regime across Riau peat hydrological unit, Indonesia. For Soc 7 (1): 76-94. DOI: 10.24259/FS.V7I1.21996.
Salve A, Bhardwaj DR, Tahkur CL. 2018. Floristic composition and distribution pattern of plant communities under different agroforestry systems in Kinnaur, North-Western Himalayas. Res J Chem Environ Sci 2018: 34-51.
Sambou M, Koné B, Sambou S, Niang F, Sane S, Diatta M, Sambou H, Goudiaby A, Mbow C, Sambou B. 2024. Variation of biomass carbon stock within agroforestry systems in the Senegalese groundnut basin. Discov Sustain 5 (1): 35. DOI: 10.1007/s43621-024-00208-3.
Samosir I, Hafizianor, Yamani A. 2021. Analisis pengelolaan agroforestri tradisional pada masyarakat Desa Paraduan Kecamatan Ronggurnihuta Kabupaten Samosir. Jurnal Sylva Scienteae 4: 300-307. DOI: 10.20527/jss.v4i2.3340. [Indonesian]
Schuler HR, Alarcon GG, Joner F, dos Santos KL, Siminski A, Siddique I. 2022. Ecosystem services from ecological agroforestry in Brazil: A systematic map of scientific evidence. Land 11 (1): 83. DOI: 10.3390/land11010083.
Sharma N, Bohra B, Pragya N, Ciannella R, Dobie P, Lehmann S. 2016. Bioenergy from agroforestry can lead to improved food security, climate change, soil quality, and rural development. Food Energy Secur 5 (3): 165-183. DOI: 10.1002/fes3.87.
Siarudin M, Indrajaya Y, Hani A. 2020. Preliminary assessment on above ground carbon stock of agroforestry and monoculture crop systems in peatlands. IOP Conf Ser: Earth Environ Sci 449 (1): 012010. DOI: 10.1088/1755-1315/449/1/012010.
Siarudin M, Rahman SA, Artati Y, Indrajaya Y, Narulita S, Ardha MJ, Larjavaara M. 2021. Carbon sequestration potential of agroforestry systems in degraded landscapes in West Java, Indonesia. Forest 12 (6): 714. DOI: 10.3390/f12060714.
Sibelet N, Posada KE, Gutiérrez-Montes IA. 2019. Agroforestry systems provide firewood for livelihood improvement in Guatemala. Bois et Forêts des Tropiques 340: 91-102. DOI: 10.19182/bft2019.340.a31692.
Sileshi GW, Mafongoya PL, Nath AJ. 2020. Agroforestry systems for improving nutrient recycling and soil fertility on degraded lands. In: Dagar JC, Gupta SR, Teketay D (eds). Agroforestry for Degraded Landscapes: Recent Advances and Emerging Challenges. Springer, Singapore. DOI: 10.1007/978-981-15-4136-0.
SNI. 2011. Pengukuran dan penghitungan cadangan karbon -Pengukuran lapangan untuk penaksiran cadangan karbon hutan (ground based forest carbon accounting). Kementrian Lingkungan Hidup dan Kehutanan, Jakarta. [Indonesian]
Strobl K, Moning C, Kollmann J. 2020. Positive trends in plant, dragonfly, and butterfly diversity of rewetted montane peatlands. Restor Ecol 28 (4): 796-806. DOI: 10.1111/rec.12957.
Sudiana N. 2018. Studi Luas dan Sebaran Lahan Gambut di Kabupaten Kampar Provinsi Riau. Jurnal Alami: Jurnal Teknologi Reduksi Risiko Bencana 2 (1): 47-56. DOI: 10.29122/alami.v2i1.2816. [Indonesian]
Tadesse E, Negash M, Asfaw Z. 2021. Impacts of traditional agroforestry practices, altitudinal gradients and households' wealth status on perennial plants species composition, diversity, and structure in south-central Ethiopia. Agrofor Syst 95 (8): 1533-1561. DOI: 10.1007/s10457-021-00659-x.
Todou G, Kamblaba P, Nnanga JF, Djoebe A. 2021. Diversity and floristic composition of woody plants in traditional agrosystems of Sudano-Sahelian zone of Cameroon: Case of Meri in the Mandara Mountains. J Agric Environ Intl Dev 116 (2): 69-85. DOI: 10.36253/jaeid-13301.
Udawatta RP, Rankoth LM, Jose S. 2019. Agroforestry and biodiversity. Sustainability 11 (10): 2879. DOI: 10.3390/su11102879.
Udawatta RP, Rankoth LM, Jose S. 2021. Agroforestry for biodiversity conservation. In: Udawatta RP, Jose S (eds). Agroforestry and Ecosystem Services. Springer, Cham. DOI: 10.1007/978-3-030-80060-4_10.
Viñals E, Maneja R, Rufí-Salís M, Martí M, Puy N. 2023. Reviewing social-ecological resilience for agroforestry systems under climate change conditions. Sci Total Environ 869: 161763. DOI: 10.1016/j.scitotenv.2023.161763.
Viswanath S, Lubina PA. 2017. Traditional agroforestry systems. In: Dagar JC, Tewari VP (eds). Agroforestry: Anecdotal to Modern Science. Springer, Singapore. DOI: 10.1007/978-981-10-7650-3_3.
Weiwei L, Wenhua L, Moucheng L, Fuller AM. 2014. Traditional agroforestry systems: one type of globally important agricultural heritage systems. J Resour Ecol 5 (4): 306-313. DOI: 10.5814/j.issn.1674-764x.2014.04.004.
Widiyanto A, Hani A. 2021. Role and key success of agroforestry (A review). Jurnal Agroforestri Indonesia 4 (2): 69-80. [Indonesian]
Wirawan R. 2019. Alih fungsi lahan dan petani nenas di Desa Rimbo Panjang Kecamatan Tambang Kabupaten Kampar. JOM FISIP 6 (1): 1-3. [Indonesian]
Wiryono W, Puteri VN, Senoaji G. 2016. The diversity of plant species, the types of plant uses and the estimate of carbon stock in agroforestry system in Harapan Makmur Village, Bengkulu, Indonesia. Biodiversitas 17 (1): 249-255. DOI: 10.13057/biodiv/d170136.
Worku M, Bantihun A. 2017. Review on woody species and socio-economic roles of traditional agroforestry practices in Ethiopia. J Fund Renew Energy 7: 6. DOI: 10.4172/2090-4541.1000246.
Yoro KO, Daramola MO. 2020. CO_2 emission sources, greenhouse gases, and the global warming effect. In: Rahimpour MR, Farsi M, Makarem MA (eds). Advances in Carbon Capture. Woodhead Publishing, Duxford. DOI: 10.1016/B978-0-12-819657-1.00001-3.
Zhu X, Liu W, Chen J et al. 2020. Reductions in water, soil and nutrient losses and pesticide pollution in agroforestry practices: A review of evidence and processes. Plant Soil 453: 45-86. DOI: 10.1007/s11104-019-04377-3.