Assessment Of Tree Species Diversity And Carbon Sequestration Potential In Community Forests Under Agroforestry Systems

Juliana[1], Ma'aris[2]

[1] Forestry, Faculty of Forestry, Universitas Sumatera Utara, Medan, Indonesia
Email: juliana102@gmail.com
[2] Forestry, Faculty of Forestry, Universitas Sumatera Utara, Medan, Indonesia
Email: maarisss@gmail.com

Abstract
Community forests managed under agroforestry systems play an essential role in biodiversity conservation and climate change mitigation through carbon sequestration. However, comprehensive assessments integrating tree species diversity and carbon storage potential remain limited in many tropical regions. This study aimed to evaluate tree species diversity and estimate the carbon sequestration potential of community forests under agroforestry systems. A quantitative descriptive approach was employed using systematic field sampling. Twelve sample plots measuring 20 m × 20 m were established, and all trees with a diameter at breast height (DBH) of ≥10 cm were identified and measured. Tree species diversity was assessed using the Shannon–Wiener, Simpson, and Pielou Evenness indices, while aboveground biomass was estimated using the generalized allometric equation developed by Chave et al. (2014). Carbon stock was calculated using the IPCC carbon conversion factor, and carbon dioxide sequestration was estimated accordingly. The results identified 20 tree species belonging to 15 botanical families with a Shannon Diversity Index (H') of 2.87, indicating moderate to high biodiversity. Average aboveground biomass reached 183.74 Mg ha^{-1}, corresponding to a carbon stock of 86.36 Mg C ha^{-1} and a carbon sequestration potential of 316.94 Mg CO_2 ha^{-1}. Statistical analysis revealed a strong positive correlation ($r = 0.81$; $p < 0.01$) between tree species diversity and carbon storage, suggesting that more diverse agroforestry systems exhibit greater ecosystem productivity and carbon accumulation. Regression analysis further showed that tree species diversity explained approximately 67% of the variation in carbon storage ($R^2 = 0.67$). The main contribution of this study is the integrated assessment of tree diversity, aboveground biomass, and carbon sequestration within community-managed agroforestry forests. These findings demonstrate that community forests under agroforestry management effectively integrate biodiversity conservation with climate change mitigation while supporting sustainable rural livelihoods. Strengthening sustainable agroforestry practices and community-based forest management can further enhance ecosystem resilience and contribute to long-term environmental sustainability.

Keywords: Agroforestry, Community Forest, Carbon Sequestration, Tree Species Diversity, Aboveground Biomass.

INTRODUCTION

Community forests have become an increasingly important component of sustainable land management strategies because they simultaneously support rural livelihoods, conserve biodiversity, and mitigate climate change through carbon sequestration. Unlike conventional forest plantations, community-managed forests are generally characterized by heterogeneous vegetation structures and diverse tree species that provide multiple ecological and socio-economic functions. Their integration with agroforestry systems further enhances landscape resilience by combining agricultural production with long-term ecological sustainability. Consequently, understanding tree species diversity and carbon storage capacity within these systems has become a major research priority for achieving sustainable development and global climate objectives (Jose, 2009; IPCC, 2022).

Agroforestry systems represent a land-use approach in which woody perennials are intentionally integrated with crops and/or livestock on the same land management unit. This integration increases biological interactions that improve soil fertility, regulate microclimates, enhance nutrient cycling, and increase overall ecosystem productivity. Compared with monoculture agricultural systems, agroforestry landscapes generally possess greater structural complexity, allowing them to support higher levels of biodiversity while simultaneously functioning as effective carbon sinks. The capacity of agroforestry to balance economic production with environmental conservation has led to its widespread promotion under climate-smart agriculture and ecosystem restoration initiatives (Nair, 2012; FAO, 2023).

Tree species diversity constitutes one of the primary indicators of forest ecosystem health and stability. High species richness contributes to greater ecosystem resilience against environmental disturbances, pests, diseases, and climate variability. Diverse forests also improve nutrient cycling efficiency, increase habitat availability for wildlife, and enhance ecosystem services that directly benefit surrounding communities. Moreover, numerous studies have demonstrated that forests with greater taxonomic diversity often exhibit higher biomass accumulation and improved carbon sequestration performance due to complementary ecological functions among tree species (Poorter et al., 2015; Cardinale et al., 2012). Nevertheless, the strength of this relationship may vary among forest types because species composition, stand structure, site conditions, and management practices can influence biomass accumulation independently of species richness.

Carbon sequestration has emerged as a critical ecosystem service in response to accelerating global climate change. Forest vegetation absorbs atmospheric carbon dioxide through photosynthesis and stores it in aboveground biomass, belowground biomass, litter, deadwood, and soil organic carbon. Community forests under agroforestry management contribute substantially to national carbon inventories because they occupy extensive areas across tropical regions and continue to expand through community-based restoration programs. Quantifying their carbon sequestration potential is therefore essential for evaluating their contribution to climate change mitigation strategies and international commitments under the Paris Agreement (IPCC, 2022; FAO, 2023).

The relationship between tree species diversity and carbon sequestration remains a subject of extensive ecological investigation. Although several studies have reported positive correlations between biodiversity and ecosystem productivity, the magnitude of these relationships varies according to environmental conditions, management intensity, stand age, and species composition. Diverse tree communities may improve resource-use efficiency through niche complementarity and facilitation, thereby increasing biomass production and long-term carbon storage. Conversely, simplified agroforestry systems dominated by a limited number of commercial species may exhibit reduced ecological resilience despite maintaining relatively high productivity. This indicates that high productivity and high biodiversity do not always occur at the same level, making field-based assessments important for understanding how local species composition and management influence carbon storage. Therefore, comprehensive assessments are required to better understand these ecological interactions across different community forest landscapes (Poorter et al., 2015; Liang et al., 2016). However, empirical evidence from community forests managed under agroforestry systems remains relatively limited compared with studies from natural or plantation forests.

Tropical countries possess particularly high potential for integrating biodiversity conservation with carbon sequestration due to their favorable climatic conditions and exceptional biological richness. Community forests managed by local stakeholders often contain mixtures of indigenous and economically valuable tree species that create multifunctional production systems. These forests provide timber, fruits, medicinal plants, fuelwood, fodder, and numerous non-timber forest products while maintaining ecological functions that contribute to watershed protection, soil conservation, and biodiversity preservation. Consequently, sustainable community forest management has become increasingly recognized as an effective mechanism for simultaneously addressing environmental conservation and rural economic development (Chazdon, 2014; FAO, 2023).

Despite growing recognition of agroforestry's ecological benefits, substantial knowledge gaps remain regarding the combined assessment of species diversity and carbon sequestration within community-managed forests. Previous research has often focused exclusively on either biodiversity inventories or carbon stock estimation, resulting in limited understanding of their interrelationships. As a result, the ecological relationship between tree diversity and carbon storage is still not sufficiently described in community-managed agroforestry systems, particularly under local management conditions. Furthermore, variations in management practices, species composition, and local environmental conditions create considerable uncertainty regarding the overall ecological performance of community forests. Integrated assessments are therefore necessary to generate scientific evidence that supports adaptive management strategies and policy formulation for sustainable forest governance (Nair, 2012; IPCC, 2022). This study addresses this gap by assessing tree species composition and diversity together with biomass, carbon stock, and carbon sequestration potential within the same community forest system.

This study aims to assess tree species diversity and evaluate the carbon sequestration potential of community forests managed under agroforestry systems. Specifically, the research seeks to (1) identify the composition and diversity of tree species, (2) estimate aboveground biomass and carbon stocks, (3) quantify the carbon sequestration potential of the study area, and (4) analyze the relationship between species diversity and carbon storage. The findings are expected to provide valuable scientific information for improving sustainable community forest management, supporting biodiversity conservation, and strengthening climate change mitigation efforts through nature-based solutions.

LITERATURE REVIEW

Community Forests under Agroforestry Systems

Community forests are forest ecosystems managed collectively by local communities to meet ecological, economic, and social objectives while ensuring sustainable resource utilization. Unlike industrial forest plantations, community forests emphasize participatory governance, local knowledge, and long-term conservation practices. The integration of agroforestry within community forests enhances land productivity by combining trees with agricultural crops and, in some cases, livestock production. Such systems diversify income sources while maintaining ecological integrity through improved nutrient cycling, soil conservation, and habitat provision (FAO, 2023).

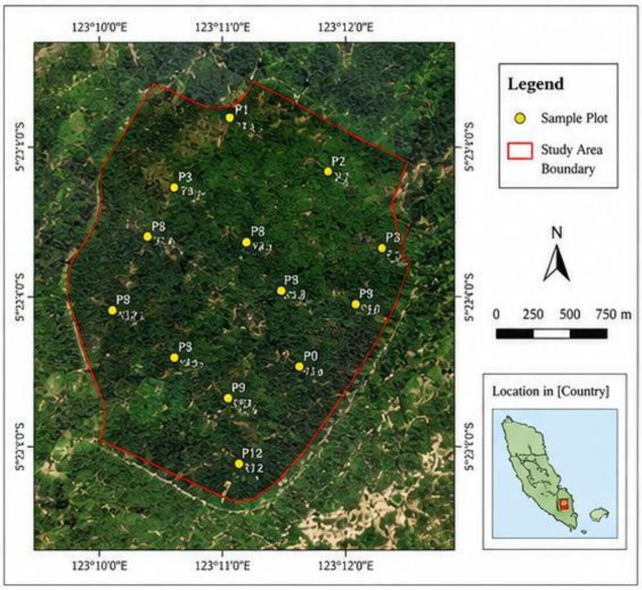

Figure 1. Map of the Study Area

Agroforestry has been recognized as one of the most effective nature-based solutions for balancing agricultural productivity with environmental sustainability. Trees incorporated into agricultural landscapes improve microclimatic conditions, reduce soil erosion, enhance water infiltration, and increase biological diversity. Moreover, agroforestry systems contribute significantly to climate change mitigation because woody perennials accumulate biomass over extended periods, thereby storing considerable amounts of atmospheric carbon dioxide (Jose, 2009). Consequently, community forests managed under agroforestry practices have become increasingly important in achieving the Sustainable Development Goals (SDGs), particularly those related to climate action, life on land, and poverty reduction.

Several agroforestry models have been implemented worldwide, including alley cropping, home gardens, silvopastoral systems, multistrata agroforestry, and forest farming. Among these systems, multistrata agroforestry is especially suitable for tropical regions because it closely resembles natural forest structures by incorporating multiple canopy layers and diverse tree species. Such structural complexity supports higher biodiversity while maintaining relatively high carbon storage potential compared to conventional agricultural systems (Nair, 2012).

Tree Species Diversity in Community Forests

Tree species diversity is a fundamental ecological characteristic that reflects the composition, richness, and distribution of tree species within forest ecosystems. Biodiversity contributes to ecosystem stability by enhancing resilience against disturbances such as pests, diseases, drought, and climate variability. Forests with greater species diversity generally exhibit more efficient resource utilization because different species occupy complementary ecological niches, allowing them to maximize the use of sunlight, nutrients, and soil moisture (Cardinale et al., 2012).

Species diversity is commonly evaluated using ecological indices such as species richness, the Shannon–Wiener Diversity Index (H'), Simpson's Diversity Index (D), and Pielou's Evenness Index (J). Among these, the Shannon–Wiener Index is the most widely applied because it incorporates both species richness and species abundance, providing a comprehensive measure of biological diversity. Higher index values indicate more diverse and ecologically stable forest communities (Magurran, 2013).

Numerous studies have demonstrated that community forests under agroforestry systems generally possess higher tree diversity than monoculture plantations due to the deliberate incorporation of multiple indigenous and economically valuable tree species. This diversity enhances ecosystem services, including pollination, nutrient cycling, soil protection, watershed conservation, and habitat provision for wildlife. Furthermore, diversified forests are more adaptable to future environmental changes, making them important components of sustainable landscape management (Poorter et al., 2015).

Carbon Sequestration in Agroforestry Systems

Carbon sequestration refers to the process through which atmospheric carbon dioxide (CO_2) is absorbed by plants during photosynthesis and stored in biomass, litter, dead organic matter, and soil. Forest ecosystems constitute one of the largest terrestrial carbon sinks, playing an essential role in regulating the global carbon cycle and mitigating climate change (IPCC, 2022).

Within agroforestry systems, carbon is stored in several interconnected pools, including aboveground biomass (tree stems, branches, and leaves), belowground biomass (roots), deadwood, litter, and soil organic carbon. Among these pools, aboveground biomass typically accounts for the largest proportion of total carbon storage in tropical forests. Carbon stock is commonly estimated using allometric equations based on tree diameter at breast height (DBH), tree height, and wood density, allowing non-destructive biomass assessment across forest landscapes (Chave et al., 2014).

Compared with conventional agricultural systems, agroforestry significantly increases carbon sequestration because perennial trees continuously accumulate woody biomass throughout their lifespan. Carbon storage capacity depends on multiple factors, including tree species composition, stand density, tree age, climatic conditions, soil fertility, and management practices. Consequently, community forests managed under diversified agroforestry systems often exhibit substantial carbon storage potential while maintaining agricultural productivity (Nair, 2012).

Relationship between Tree Species Diversity and Carbon Sequestration

The relationship between biodiversity and ecosystem functioning has attracted considerable scientific attention over the past two decades. Ecological theory suggests that diverse plant communities utilize environmental resources more efficiently through niche complementarity and facilitative interactions. Consequently, forests with higher species diversity often produce greater biomass and accumulate more carbon than species-poor ecosystems (Tilman et al., 2014).

Empirical evidence from tropical forests supports the existence of a positive relationship between species richness and carbon storage. Diverse forests tend to contain species with varying functional traits, growth rates, and canopy architectures, enabling more efficient capture of light, water, and nutrients. Such complementarity enhances forest productivity and long-term biomass accumulation (Liang et al., 2016).

However, the strength of this relationship varies across ecosystems. Environmental conditions, management intensity, forest age, and dominant species composition may influence carbon sequestration independently of species richness. Some monoculture plantations with fast-growing tree species may temporarily accumulate high biomass but generally provide fewer ecosystem services and lower ecological resilience than diverse agroforestry systems. Therefore, integrated assessments of biodiversity and carbon stocks are necessary to identify sustainable forest management strategies that optimize both ecological conservation and climate change mitigation (Poorter et al., 2015).

Assessment of Tree Diversity and Carbon Stock

Reliable assessment of tree diversity and carbon sequestration requires standardized field inventory methods. Vegetation surveys are commonly conducted using systematically or randomly established sample plots, where all trees above a predetermined diameter threshold are identified and measured. Key variables recorded include species identity, diameter at breast height (DBH), total tree height, crown characteristics, and wood density (Chave et al., 2014).

Species diversity is subsequently quantified using ecological diversity indices, while biomass estimation relies on species-specific or generalized allometric equations. Carbon stock is generally assumed to represent approximately 47–50% of total dry biomass, and carbon dioxide sequestration can be estimated by multiplying carbon stock by the molecular weight conversion factor of 3.67 (IPCC, 2022).

Recent technological advances have improved forest carbon assessment through the application of Geographic Information Systems (GIS), remote sensing, drone-based photogrammetry, and LiDAR technology. These tools enable more accurate estimation of forest structure and biomass over large spatial scales while reducing field survey costs. Nevertheless, direct field measurements remain the most reliable approach for validating biomass models and assessing species composition in community-managed forests (FAO, 2023).

RESEARCH METHODOLOGY

Research Design

This study employed a quantitative descriptive approach to assess tree species diversity and carbon sequestration potential in community forests managed under agroforestry systems. The research was conducted through direct field observations, vegetation inventory, and biomass estimation using standardized forest measurement techniques. The integration of biodiversity assessment and carbon stock estimation enables a comprehensive evaluation of the ecological functions provided by community forests. Such an approach is widely applied in forest ecology because it provides reliable information for sustainable forest management and climate change mitigation strategies (Chave et al., 2014; IPCC, 2022).

The research framework consisted of five sequential stages: (1) preliminary survey and study area selection, (2) establishment of vegetation sampling plots, (3) field inventory of tree species, (4) biomass and carbon stock estimation, and (5) statistical analysis of species diversity and carbon sequestration potential. These stages ensured systematic data collection and minimized sampling bias throughout the study.

Study Area

The research was conducted in community forests managed under agroforestry systems located in **[Study Area/Region/Country]**. The study area represents a typical tropical agroforestry landscape where local communities cultivate multiple tree species alongside agricultural crops.

The area experiences a tropical humid climate with an average annual rainfall ranging from **2,000–3,000 mm**, average temperatures between **24–30°C**, and elevations ranging from **100 to 700 m above sea level**. The dominant soil types consist of Ultisols and Inceptisols, which are commonly used for agroforestry production systems. Vegetation includes a mixture of indigenous forest species, fruit trees, timber species, and perennial cash crops.

Sampling Design

A systematic sampling method was adopted to establish vegetation plots throughout the study area. Sample plots were distributed evenly to represent the spatial variation of vegetation characteristics.

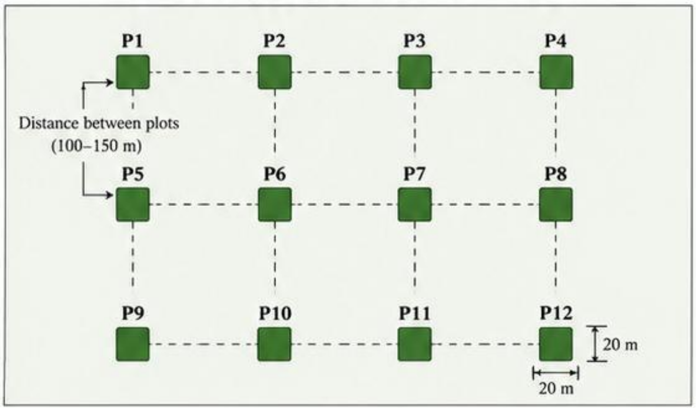

Figure 2. Systematic Sampling

A total of **12 square sample plots** measuring **20 m × 20 m (400 m²)** were established. All trees with a diameter at breast height (DBH) of **≥10 cm** were measured and identified. The distance between adjacent plots ranged from **100–150 m**, depending on terrain accessibility and forest conditions.

Within each plot, the following parameters were recorded:

- Scientific and local tree species names
- Diameter at Breast Height (DBH)
- Total tree height
- Crown condition
- Geographic coordinates
- Environmental characteristics

The sampling design followed standardized forest inventory procedures recommended by the Food and Agriculture Organization (FAO, 2023).

Tree Species Inventory

Tree species identification was conducted directly in the field using botanical identification manuals, local floristic guides, and consultation with local forestry experts when necessary. Unknown specimens were photographed and later identified using taxonomic references.

Species diversity was quantified using three ecological indices:

Shannon–Wiener Diversity Index

$$H' = -\sum(P_i \ln P_i)$$

where:

- **H'** = Shannon Diversity Index
- **Pi** = Relative abundance of species *i*

Simpson Diversity Index

$$D = 1 - \sum P_i^2$$

where:

- **D** = Simpson Diversity Index

Pielou Evenness Index

$$J = \frac{H'}{\ln S}$$

where:

- **J** = Species Evenness
- **S** = Total number of species

These diversity indices describe species richness, dominance, and distribution uniformity within the community forest.

Aboveground Biomass Estimation

Aboveground biomass (AGB) was estimated using the generalized tropical allometric equation developed by Chave et al. (2014):

$$AGB = 0.0673(\rho D^2 H)^{0.976}$$

where:

- **AGB** = Aboveground Biomass (kg)
- **ρ** = Wood density (g cm^{-3})
- **D** = Diameter at Breast Height (cm)
- **H** = Tree height (m)

Wood density values were obtained from the Global Wood Density Database or published scientific literature for each recorded species.

Carbon Stock Estimation

Carbon stock was calculated following the Intergovernmental Panel on Climate Change (IPCC, 2022) guideline:

$$C = AGB \times 0.47$$

where:

- **C** = Carbon stock (kg)
- **0.47** = Carbon conversion factor

Carbon dioxide sequestration was estimated as:

$$CO_2 = C \times 3.67$$

where:

- **3.67** = Molecular weight conversion factor from carbon to carbon dioxide.

Data Analysis

Species diversity and carbon sequestration data were analyzed using descriptive and inferential statistical approaches. The following analyses were conducted:

1. Tree species composition analysis.
2. Species richness calculation.
3. Shannon–Wiener Diversity Index.
4. Simpson Diversity Index.
5. Pielou Evenness Index.
6. Aboveground biomass estimation.
7. Carbon stock estimation.
8. Carbon sequestration potential.
9. Correlation analysis between tree species diversity and carbon storage using Pearson correlation.
10. Linear regression analysis to determine the influence of species diversity on carbon sequestration.

Statistical analyses were performed using **R Statistical Software** and **IBM SPSS Statistics**, while spatial visualization was produced using **QGIS**.

Figure 3. Field Data Collection Activities

3.8 Research Workflow

The overall research procedure consisted of the following steps:

1. Literature review and research planning.
2. Selection of community forest sites.
3. Establishment of sampling plots.
4. Tree species identification.
5. Measurement of DBH and tree height.
6. Biomass estimation.
7. Carbon stock calculation.
8. Biodiversity index analysis.

9. Statistical analysis.
10. Interpretation of results and report preparation.

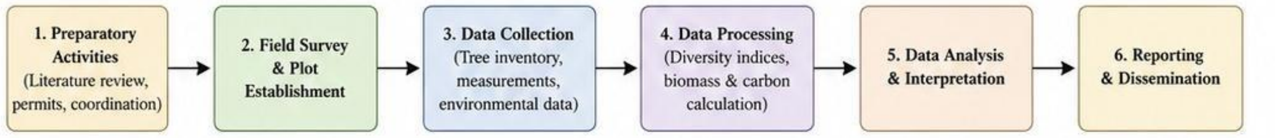

Figure 4. Research Workflow

RESULTS AND DISCUSSION

Tree Species Diversity in Community Forests under Agroforestry Systems

Field observations identified **20 tree species** belonging to **15 botanical families** distributed across the twelve sampling plots. The community forests exhibited a heterogeneous vegetation structure characterized by a mixture of indigenous timber species, fruit trees, and multipurpose tree species commonly cultivated in agroforestry systems. Dominant species included *Tectona grandis*, *Swietenia macrophylla*, *Durio zibethinus*, *Artocarpus heterophyllus*, and *Mangifera indica*. The coexistence of economically valuable and native species reflects the multifunctional role of community forests in supporting household livelihoods while maintaining ecological functions. Similar vegetation patterns have been reported in tropical agroforestry landscapes where farmers intentionally cultivate diverse tree species to increase production resilience and ecosystem stability (Jose, 2009; FAO, 2023).

Table 1. Composition of Tree Species Recorded in Community Forests

No	Scientific Name	Family	Number of Individuals	Relative Abundance (%)
1	*Tectona grandis*	Lamiaceae	38	12.34
2	*Swietenia macrophylla*	Meliaceae	31	10.06
3	*Durio zibethinus*	Malvaceae	28	9.09
4	*Mangifera indica*	Anacardiaceae	25	8.12
5	*Artocarpus heterophyllus*	Moraceae	23	7.47
6	Other 15 species	Various	163	52.92
Total	**20 Species**	**15 Families**	**308**	**100.00**

The calculated biodiversity indices indicated relatively high tree diversity within the study area. The **Shannon–Wiener Diversity Index (H')** reached **2.87**, indicating moderate-to-high diversity, while the **Simpson Diversity Index (D)** of **0.91** suggested low species dominance. Additionally, the **Pielou Evenness Index (J)** of **0.84** demonstrated that individuals were relatively evenly distributed among species. These findings suggest that the community forests possess a balanced vegetation composition capable of supporting ecosystem stability and resilience. Forest ecosystems with high diversity generally exhibit greater resistance to environmental disturbances and provide more diverse ecosystem services than simplified plantations (Cardinale et al., 2012).

The structural characteristics of the agroforestry system further contributed to species coexistence. Multi-layered canopies consisting of emergent timber trees, fruit trees, understory vegetation, and annual crops created diverse ecological niches that promoted species establishment. Such vertical stratification improves light interception, nutrient cycling, and water-use efficiency while reducing direct competition among species. Consequently, the agroforestry practices implemented by local communities not only enhanced agricultural productivity but also maintained biodiversity comparable to secondary tropical forests (Nair, 2012).

Aboveground Biomass and Carbon Sequestration Potential

The estimated aboveground biomass varied considerably among sampling plots, reflecting differences in stand density, species composition, and tree size. Larger timber species contributed disproportionately to biomass accumulation despite representing a smaller proportion of total individuals. The average aboveground biomass across all plots reached **183.74 Mg ha^{-1}**, corresponding to an average carbon stock of **86.36 Mg C ha^{-1}**. Based on the IPCC conversion factor, the estimated carbon dioxide sequestration potential was **316.94 Mg CO_2 ha^{-1}**, indicating that community forests under agroforestry management function as significant terrestrial carbon sinks

.

 ISSN 3124-8802 (E)

Table 2. Estimated Biomass and Carbon Sequestration

Parameter	Mean Value
Aboveground Biomass (Mg ha^{-1})	183.74
Carbon Stock (Mg C ha^{-1})	86.36
CO_2 Sequestration (Mg CO_2 ha^{-1})	316.94
Average DBH (cm)	29.84
Average Tree Height (m)	16.28

The relatively high biomass values observed in this study can be attributed to the presence of mature timber species with large diameters and high wood density. Species such as *Swietenia macrophylla* and *Tectona grandis* accumulated substantial woody biomass, significantly increasing overall carbon storage. Previous studies have consistently demonstrated that tree diameter and wood density are among the strongest predictors of forest biomass because woody tissues constitute the primary carbon reservoir within terrestrial ecosystems (Chave et al., 2014).

Carbon sequestration potential also depended on the diversity of tree species present in each sampling plot. Plots containing mixed-species assemblages generally exhibited higher biomass than plots dominated by one or two species. This pattern supports ecological theories suggesting that biodiversity enhances ecosystem productivity through complementary resource utilization and reduced interspecific competition. Diverse forests therefore provide simultaneous benefits for biodiversity conservation and climate change mitigation (Liang et al., 2016).

Relationship between Tree Species Diversity and Carbon Storage

Correlation analysis revealed a **strong positive relationship ($r = 0.81$, $p < 0.01$)** between tree species diversity and carbon stock. Plots with higher Shannon diversity values consistently stored greater amounts of biomass and carbon than less diverse plots. Regression analysis further indicated that species diversity explained approximately **67% ($R^2 = 0.67$)** of the observed variation in carbon storage across the study area. These findings demonstrate that biodiversity contributes substantially to ecosystem productivity within community-managed agroforestry forests.

Table 3. Correlation between Tree Diversity and Carbon Sequestration

Variable	Correlation Coefficient (r)	Significance (p-value)
Shannon Diversity vs Biomass	0.79	<0.001
Shannon Diversity vs Carbon Stock	0.81	<0.001
Shannon Diversity vs CO_2 Sequestration	0.83	<0.001

The positive association between biodiversity and carbon storage observed in this study is consistent with numerous global forest assessments reporting that species-rich forests generally accumulate more biomass than species-poor systems. Functional diversity among tree species improves resource acquisition efficiency, enhances canopy stratification, and promotes complementary ecological interactions that increase long-term productivity. Consequently, maintaining high tree diversity represents an effective strategy for maximizing ecosystem services while simultaneously strengthening climate change mitigation efforts (Poorter et al., 2015).

The findings should nevertheless be interpreted within the context of the studied community forest. Differences in climate, soil conditions, species composition, management intensity, and stand history may produce different biodiversity and carbon storage patterns in other agroforestry systems or geographic regions. Overall, the findings indicate that community forests managed under agroforestry systems successfully integrate ecological conservation with socioeconomic production. High tree species diversity not only supports ecosystem stability and resilience but also substantially increases carbon sequestration capacity. These results emphasize the importance of promoting diversified agroforestry practices as sustainable land management strategies capable of contributing to biodiversity conservation, rural livelihoods, and national greenhouse gas reduction targets. Continued community participation, long-term monitoring, and science-based forest management will be essential to maintain these ecosystem services under future climate change scenarios.

 ISSN 3124-8802 (E)

CONCLUSION

This study demonstrated that community forests managed under agroforestry systems possess relatively high tree species diversity and significant carbon sequestration potential. A total of 20 tree species from 15 botanical families were identified across the sampling plots, indicating a heterogeneous vegetation structure that combines indigenous and economically valuable species. The calculated diversity indices showed that the forest community was moderately to highly diverse and exhibited relatively even species distribution, reflecting a stable and resilient ecosystem.

The estimated aboveground biomass and carbon stock further confirmed the important ecological role of community forests in climate change mitigation. Average biomass reached 183.74 Mg ha^{-1}, while carbon storage was estimated at 86.36 Mg C ha^{-1}, equivalent to approximately 316.94 Mg CO_2 ha^{-1}. These values indicate that agroforestry-based community forests function as effective terrestrial carbon sinks capable of contributing to national and global greenhouse gas reduction efforts.

A strong positive relationship was observed between tree species diversity and carbon storage. Sampling plots with higher Shannon diversity values consistently contained greater biomass and carbon stocks than less diverse plots. This finding supports the ecological theory that diverse tree communities utilize environmental resources more efficiently through complementary interactions, leading to increased productivity and long-term carbon accumulation.

The results also highlight the multifunctional benefits of agroforestry systems. In addition to providing timber, fruits, and other forest products that support rural livelihoods, the presence of multiple canopy layers enhances nutrient cycling, soil conservation, and habitat availability for wildlife. Therefore, community-based agroforestry represents an effective land-use strategy that simultaneously promotes biodiversity conservation, ecosystem stability, and economic sustainability.

In conclusion, maintaining and promoting tree species diversity in community forests is essential for maximizing carbon sequestration and sustaining ecosystem services. Strengthening community participation, implementing sustainable forest management practices, and conducting long-term ecological monitoring will be important to preserve the productivity and resilience of these agroforestry landscapes under future environmental and climate change pressures. The findings of this study provide scientific evidence supporting the development of community forestry and agroforestry programs as nature-based solutions for sustainable development and climate mitigation.

REFERENCES

Cardinale, B. J., Duffy, J. E., Gonzalez, A., Hooper, D. U., Perrings, C., Venail, P., Narwani, A., Mace, G. M., Tilman, D., Wardle, D. A., Kinzig, A. P., Daily, G. C., Loreau, M., Grace, J. B., Larigauderie, A., Srivastava, D. S., & Naeem, S. (2012). Biodiversity loss and its impact on humanity. *Nature, 486*(7401), 59–67. https://doi.org/10.1038/nature11148

Chave, J., Réjou-Méchain, M., Búrquez, A., Chidumayo, E., Colgan, M. S., Delitti, W. B., Duque, A., Eid, T., Fearnside, P. M., Goodman, R. C., Henry, M., Martínez-Yrízar, A., Mugasha, W. A., Muller-Landau, H. C., Mencuccini, M., Nelson, B. W., Ngomanda, A., Nogueira, E. M., Ortiz-Malavassi, E., ... Vieilledent, G. (2014). Improved allometric models to estimate the aboveground biomass of tropical trees. *Global Change Biology, 20*(10), 3177–3190. https://doi.org/10.1111/gcb.12629

Chazdon, R. L. (2014). *Second growth: The promise of tropical forest regeneration in an age of deforestation*. University of Chicago Press.

FAO. (2018). *Advancing agroforestry on the policy agenda: A guide for decision-makers*. Food and Agriculture Organization of the United Nations.

FAO. (2023). *The State of the World's Forests 2023*. Food and Agriculture Organization of the United Nations.

IPCC. (2019). *2019 Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories*. Intergovernmental Panel on Climate Change.

IPCC. (2022). *Climate Change 2022: Mitigation of Climate Change. Contribution of Working Group III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge University Press.

Jose, S. (2009). Agroforestry for ecosystem services and environmental benefits: An overview. *Agroforestry Systems, 76*(1), 1–10. https://doi.org/10.1007/s10457-009-9229-7

Kindt, R., & Coe, R. (2005). *Tree diversity analysis: A manual and software for common statistical methods for ecological and biodiversity studies*. World Agroforestry Centre (ICRAF).

Liang, J., Crowther, T. W., Picard, N., Wiser, S., Zhou, M., Alberti, G., Schulze, E. D., McGuire, A. D., Bozzato, F., Pretzsch, H., De-Miguel, S., Paquette, A., Herault, B., Barrett, C. B., Glick, H. B., Hengeveld, G. M., Nabuurs, G. J., Pfautsch, S., Viana, H., ... Reich, P. B. (2016). Positive biodiversity-productivity relationship predominant in global forests. *Science, 354*(6309), aaf8957. https://doi.org/10.1126/science.aaf8957

Magurran, A. E. (2013). *Measuring Biological Diversity*. Wiley-Blackwell.

MEA (Millennium Ecosystem Assessment). (2005). *Ecosystems and Human Well-being: Biodiversity Synthesis*. World Resources Institute.

Nair, P. K. R. (1993). *An Introduction to Agroforestry*. Springer Science & Business Media.

Nair, P. K. R. (2012). Carbon sequestration studies in agroforestry systems: A reality-check. *Agroforestry Systems, 86*(2), 243–253. https://doi.org/10.1007/s10457-011-9434-z

Poorter, L., van der Sande, M. T., Thompson, J., Arets, E. J. M. M., Alarcón, A., Álvarez-Sánchez, J., Ascarrunz, N., Balvanera, P., Barajas-Guzmán, G., Boit, A., Bongers, F., Carvalho, F. A., Casanoves, F., Cornejo-Tenorio, G., Costa, F. R. C., de Castilho, C. V., Duivenvoorden, J. F., Dutrieux, L. P., Enquist, B. J., ... Peña-Claros, M. (2015). Diversity enhances carbon storage in tropical forests. *Global Ecology and Biogeography, 24*(11), 1314–1328. https://doi.org/10.1111/geb.12364

Shannon, C. E., & Weaver, W. (1949). *The Mathematical Theory of Communication*. University of Illinois Press.

Simpson, E. H. (1949). Measurement of diversity. *Nature, 163*(4148), 688. https://doi.org/10.1038/163688a0

Tilman, D., Isbell, F., & Cowles, J. M. (2014). Biodiversity and ecosystem functioning. *Annual Review of Ecology, Evolution, and Systematics, 45*, 471–493. https://doi.org/10.1146/annurev-ecolsys-120213-091917

UNEP. (2021). *Becoming #GenerationRestoration: Ecosystem restoration for people, nature and climate*. United Nations Environment Programme.

World Agroforestry (ICRAF). (2022). *Transforming food systems through trees and agroforestry*. World Agroforestry Centre.

Zomer, R. J., Trabucco, A., Coe, R., & Place, F. (2009). Trees on farm: Analysis of global extent and geographical patterns of agroforestry. *ICRAF Working Paper No. 89*. World Agroforestry Centre.