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Aboveground Carbon Stocks Following Multi-Purpose Tree Species Enrichment in a Community-Based Forest Management Area in Central Lombok

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ABSTRACT

Community-based forest management has been widely implemented in Indonesia to reconcile local livelihoods with forest conservation objectives. This study evaluates the ecological outcomes of a multi-purpose tree species (MPTS) enrichment program implemented in 2017 within a community forest (HKm) in Lantan Village, Central Lombok. Field assessments conducted between April and October 2024 combined vegetation inventories, farmer interviews, and biophysical measurements to assess post-enrichment vegetation structure and aboveground carbon stocks. Seven years after enrichment, vegetation composition remained strongly influenced by farmer management. A total of 25 plant species were recorded, comprising timber species, MPTS, and understory vegetation. Banana (*Musa* spp.) dominated larger diameter classes, while coffee (*Coffea* spp.) prevailed in smaller classes, reflecting short-term livelihood priorities. Mean aboveground carbon stock was estimated at 36.8 t ha^{-1}, with timber species contributing the largest share, followed by banana, MPTS, and litter. Enrichment-planted MPTS contributed only a small proportion of total carbon stocks due to their young age and limited diameter growth. Overall, enrichment planting increased species diversity but resulted in modest medium-term carbon gains. Reducing banana dominance and promoting long-term tree growth, including MPTS, are essential to enhance ecological sustainability and carbon sequestration in HKm.

1. INTRODUCTION

Forests play a critical role in climate change mitigation through their capacity to sequester atmospheric carbon and store it in above- and belowground biomass [1]. Beyond carbon regulation, forests provide essential hydrological services by influencing interception, infiltration, runoff, and soil erosion processes [2, 3]. Forest landscapes also support rural livelihoods by supplying income and subsistence resources, particularly for communities living adjacent to forested areas [4-6]. Land-use change and forest degradation can significantly reduce biodiversity and ecosystem carbon storage, while forest restoration and sustainable land management practices can enhance biomass accumulation and ecological resilience [7-9]. However, forests located near settlements are highly vulnerable to degradation due to increasing human pressure and intensified resource extraction.

In response to these challenges, community-based forest management has been promoted as a strategy to address forest degradation, reduce deforestation, and mitigate conflicts over forest resource use [10, 11]. Empirical evidence indicates that community-managed forests under Indonesia's Social Forestry Program—including the community forest (*Hutan Kemasyarakatan*, HKm) and village forest (*Hutan Desa*, HD) schemes—can improve forest condition, optimize land use, enhance carbon uptake, and contribute to local livelihoods [12-14]. Several studies further demonstrate that community forestry initiatives can reduce deforestation, increase carbon sequestration, and simultaneously improve rural welfare and household income [10, 12-15]. Such management approaches are expected to support national climate commitments, including Indonesia’s Forestry and Other Land Use (FOLU) Net Sink 2030 target [16]. Nevertheless, community management does not automatically guarantee ecological sustainability. When short-term economic objectives dominate management decisions, ecological functions such as biomass accumulation and carbon storage may decline.

The selection of tree species and cultivation systems that align livelihood benefits with long-term ecological functions is, therefore, a key design challenge in HKm. Previous studies suggest that multi-strata agroforestry systems incorporating multi-purpose tree species (MPTS) can encourage community participation while maintaining tree cover and ecosystem services [17, 18]. Increasing the proportion of MPTS has also been proposed as an approach to reduce land tenure conflicts and improve management outcomes in socially managed forest landscapes [19]. Agroforestry systems integrating timber and non-timber tree species are widely recognized as effective restoration strategies that simultaneously support ecological recovery and livelihood diversification in degraded forest landscapes [18, 20-22]. Recent studies have highlighted the multifunctional role of agroforestry systems in enhancing biodiversity conservation, carbon sequestration, ecosystem services, and livelihood resilience across tropical landscapes

[23, 24]. Species-diverse agroforestry systems can enhance ecosystem functioning by improving habitat quality, supporting biodiversity conservation, and providing a wider range of ecosystem services within agricultural landscapes [25, 26]. Consequently, the incorporation of MPTS into agroforestry systems can contribute to both environmental sustainability and rural livelihoods by enhancing ecosystem functions and generating a range of socioeconomic benefits for local communities [23, 27]. However, empirical evidence on the medium-term ecological outcomes of such enrichment interventions—particularly their effects on vegetation structure and carbon stocks—remains limited.

In Lombok, community participation in forest management has been extensive, with thousands of households involved in HKm schemes [28]. Lantan Village in Central Lombok represents one such case, where enrichment planting using MPTS was implemented in 2016–2017 within an HKm. The program introduced fruit-based tree species such as avocado (*Persea americana*), durian (*Durio zibethinus*), duku (*Lansium domesticum*), and mangosteen (*Garcinia mangostana*) as a management intervention intended to enhance land productivity while contributing to climate mitigation through increased biomass and soil carbon storage. However, the long-term performance and ecological implications of this intervention require systematic evaluation through post-enrichment monitoring.

Despite the increasing adoption of MPTS enrichment within HKm, important questions remain regarding its medium-term ecological effectiveness beyond the establishment phase. While enrichment planting is expected to increase vegetation diversity, promote biomass accumulation, and enhance carbon sequestration, the extent to which these outcomes are achieved under farmer-managed tropical forest conditions remains insufficiently documented. In many social forestry systems, management decisions are strongly influenced by livelihood considerations, often favoring fast-growing and economically valuable species over long-term ecological objectives. Consequently, understanding how MPTS enrichment affects vegetation composition, stand structure, and carbon storage is essential for evaluating whether community-based forest management can simultaneously achieve livelihood improvement and environmental sustainability. This study addresses this knowledge gap by examining post-enrichment vegetation structure, carbon stocks, and the growth performance of MPTS seven years after enrichment planting in an HKm landscape. Specifically, the study investigates whether MPTS enrichment contributes to improved vegetation structure and carbon storage while supporting the ecological sustainability objectives of HKm.

Accordingly, this study aims to (i) assess vegetation composition following MPTS enrichment in the HKm area of Lantan Village, (ii) quantify aboveground carbon stocks associated with enriched and existing vegetation, and (iii) examine the growth performance of enriched MPTS. The findings are expected to contribute to a better understanding of the ecological outcomes of MPTS enrichment in HKm and to inform management strategies that balance carbon sequestration, biodiversity conservation, and livelihood objectives in tropical forest landscapes.

2. MATERIALS AND METHODS

2.1 Study area

The research was conducted in a community forest (*Hutan Kemasyarakatan*, HKm) located in Lantan Village, North Batukliang Sub-district, Central Lombok, Indonesia (Figure 1). This site was selected because it represents an area where enrichment planting with MPTS was implemented in 2017 under the Millennium Challenge Account Indonesia (MCAI) program. Field data collection was carried out between April and October 2024 on farmer-managed plots that have been continuously cultivated since the enrichment intervention, allowing an assessment of medium-term ecological outcomes following planting activities.

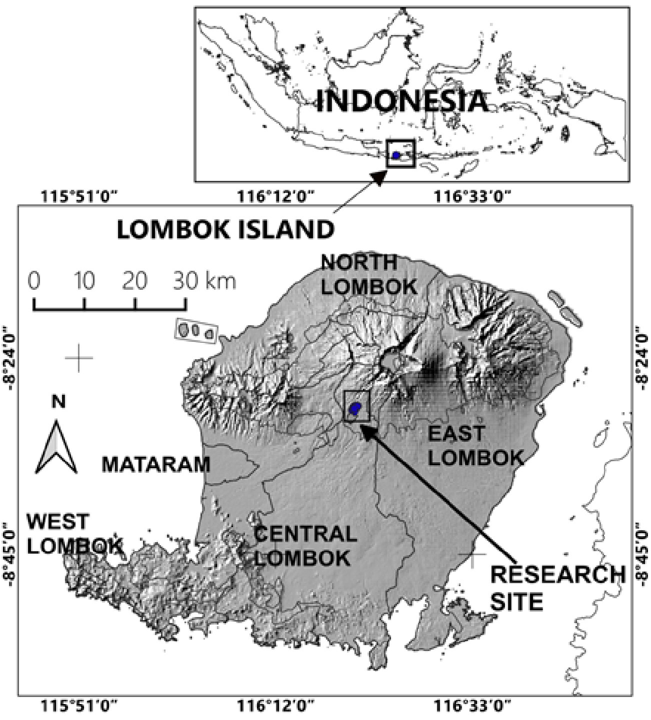

Figure 1. Location of the community forest (HKm) in Lantan Village, North Batukliang Subdistrict, Central Lombok, Indonesia, indicating the farmer-managed plots assessed in this study

Elevation within the study area ranges from 858 to 1,005 m above sea level according to DEMNAS data provided by the Indonesian Geospatial Information Agency (BIG) (https://tanahair.indonesia.go.id/portal-web/unduh/demnas). Based on the Schmidt–Ferguson climate classification, the area is categorized as climate type C (Q = 0.33–0.60), indicating a moderate proportion of dry to wet months. Mean annual rainfall recorded at the nearest meteorological station (Lingkok Lime) is approximately 2,469 mm y^{-1} [29, 30].

2.2 Sampling design and plot establishment

The enrichment area covered approximately 117.16 ha. Vegetation sampling was conducted using an area-based approach with a sampling intensity of at least 1%, consistent with plot-based forest inventory practices [31]. Accordingly, 33 fixed-area plots (400 m² each) were established, representing a total sampled area of 1.32 ha, equivalent to approximately 1.1% of the study area. The plots were distributed throughout the enrichment area, with one plot located within the landholding of each selected farmer to ensure adequate spatial representation of enrichment-planted areas across the HKm landscape. Each plot served as the primary sampling unit for vegetation measurement and carbon stock assessment.

2.3 Vegetation measurement

Vegetation data were collected within a 20 × 20 m plot established in each selected land parcel. The 20 × 20 m plot size and nested subplot design were adopted because similar fixed-area nested plots have been applied in forest and agroforestry vegetation inventories to assess stand structure, species composition, regeneration, and biomass across different vegetation strata [32]. Nested subplots of 10 × 10 m, 5 × 5 m, and 2 × 2 m were established within the main plot to represent pole, sapling, and seedling strata, respectively, following commonly applied vegetation sampling procedures in tropical forest ecosystems. This nested design allowed the simultaneous assessment of different vegetation growth stages within the same sampling unit while improving sampling efficiency and consistency across plots.

All enriched MPTS occurring within the main plot were identified and measured, including diameter at breast height (DBH) and total tree height. Other woody and non-woody vegetation were inventoried following standard forest measurement procedures commonly applied in tropical agroforestry systems. Microclimatic conditions, specifically air temperature and relative humidity, were recorded at midday using a portable thermo-hygrometer to reflect typical daytime field conditions.

2.4 Data analysis

2.4.1 Vegetation composition

Vegetation composition was assessed descriptively based on species richness, abundance, density, and diameter-class distribution following standard vegetation analysis procedures [33, 34].

2.4.2 Carbon stock estimation

Aboveground biomass (AGB) of woody vegetation was estimated using the generalized moist tropical forest allometric equation proposed by Chave et al. [35], which was developed for tropical regions with annual rainfall ranging from 1,500 to 4,000 mm y^{-1}:

$$AGB_{est} = 0.0509\rho D^2 H \quad (1)$$

where, AGB_{est} is aboveground biomass (AGB, kg), D is diameter at breast height (DBH, cm), H is total tree height (m), and ρ is wood density (g cm^{-3}). This equation was applied to tree species for which species-specific allometric equations were not available. Species-specific allometric equations were used where appropriate following established agroforestry biomass estimation procedures [34, 36]. Biomass of understory vegetation and litter was converted to carbon stock using a carbon fraction of 0.47 following SNI 7724:2011 [37].

2.4.3 Growth performance of enrichment-planted multi-purpose tree species

Growth performance of enrichment-planted MPTS was assessed descriptively using mean DBH, mean total height, abundance, and density for each species to characterize establishment success and current stand development [34].

3. RESULTS AND DISCUSSION

3.1 Species composition and vegetation structure

Field observations across the sampled plots recorded a total of 25 plant species, comprising 11 timber species, 10 MPTS, and 4 understory species (Table 1). The relatively high representation of MPTS, which accounted for a substantial proportion of all recorded species (40%), indicates that vegetation composition in the study area is strongly influenced by farmer management decisions rather than natural forest regeneration alone. This pattern reflects the emphasis placed on economically valuable species during enrichment activities and subsequent plot maintenance. Similar vegetation structures have been reported from other HKm in Lombok, where agroforestry-oriented species tend to dominate stand composition [38].

Table 1. Plant species recorded in the sample plots

No.	Timber Species	MPTS	Understory Species
1	Dao tree	Jackfruit	Taro
2	Coral tree	Avocado	Fern
3	Silk-cotton tree	Durian	Cassava
4	Palm	Coffee	Vanilla
5	White teak	Guava	–
6	Falcataria	Cacao	–
7	Borok tree	Melinjo	–
8	Royal palm	Mangosteen	–
9	Teak	Manggo	–
10	Suren tree	Banana	–
11	Areca palm	–	–

Notes: MPTS: Multi-purpose tree species. A total of 25 plant species were recorded in the sampled plots, comprising 11 timber species, 10 MPTS, and 4 understory species.

Banana (*Musa* spp.) emerged as the most abundant species group overall, accounting for approximately 69% of all recorded individuals (Table 2 and Figure 2). Banana dominated the ≥20 cm, 10–<20 cm, and seedling class, although it was not the dominant group in the 2 cm ≤ D < 10 cm class. Such dominance is not unexpected in community agroforestry systems in Lombok, where banana is widely favored for its rapid growth and short-term economic returns. In addition, bananas propagate efficiently through vegetative suckers, enabling rapid clonal expansion and high stem densities within managed plots. Similar patterns have been documented in research [28], highlighting the combined influence of species growth characteristics and livelihood-oriented farmer management in shaping vegetation composition. This dominance may also limit the recruitment and development of long-lived woody species, thereby influencing the overall vegetation structure of the HKm system.

In contrast, timber species were sparsely represented, with densities of only 52 individuals ha⁻¹ in the ≥20 cm diameter class and 18 individuals ha⁻¹ in the 10–<20 cm class. Coffee (*Coffea* spp.) accounted for 60% of all individuals in the 2 cm ≤ D < 10 cm diameter class. The absence of timber species in this size class suggests limited recruitment of long-lived woody species, either through natural regeneration or active planting. Seedling composition further supports this interpretation, as it was largely dominated by MPTS and banana, indicating that farmer management practices continue to prioritize species with immediate or short-term economic value.

Table 2. Population density of vegetation groups across diameter classes in the sampled community forest (HKm) plots (individuals ha⁻¹)

(a) Population Density (individuals ha⁻¹)					
Vegetation Group	**DBH >=20 cm**	**DBH 10-<20 cm**	**DBH ϕ 2-<10 cm**	**Seedlings**	**Total**
MPTS (non-coffee)	43	71	31	455	145
MPTS (coffee)	–	18	**364**	1,591	382
Timber species	52	18	0	–	70
Banana	**439**	**650**	215	**2,652**	**1,304**
Total	534	757	610	4,698	1,901
(b) Proportion of Individuals (%)					
Vegetation Group	**DBH >=20 cm**	**DBH 10-<20 cm**	**DBH 2-<10 cm**	**Seedlings**	**Overall (%)**
MPTS (non-coffee)	8%	9%	5%	10%	8%
MPTS (coffee)	0%	2%	**60%**	34%	20%
Timber species	10%	2%	0%	0%	4%
Banana	**82%**	**86%**	35%	**56%**	**69%**
Total	100%	100%	100%	100%	100%

Note: Dominant values within each diameter class and overall category are shown in bold. DBH: Diameter at breast height.

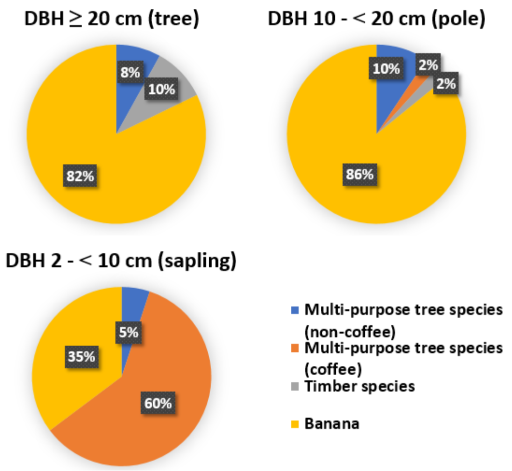

Figure 2. Composition of timber species, coffee-based and non-coffee multi-purpose tree species (MPTS), and banana across diameter classes in the community forest (HKm) of Lantan Village

These findings underscore that vegetation structure in the HKm of Lantan is largely shaped by farmer management decisions, particularly the preference for fast-growing and economically valuable species. As a result, longer-lived timber and native tree species are comparatively underrepresented. When contrasted with natural forest vegetation in Lombok [39, 40], the studied HKm system exhibits lower structural complexity and a more simplified species assemblage, a pattern commonly associated with community-based agroforestry landscapes.

From an ecological perspective, the dominance of non-timber and short-rotation species has clear implications for long-term ecosystem services. Although this composition provides short-term economic benefits, it may constrain carbon storage, hydrological regulation, and biodiversity conservation, thereby limiting overall ecological resilience and long-term carbon sequestration potential of the site.

3.2 Carbon stocks

Aboveground carbon stocks for each vegetation group and diameter class are presented in Table 3 and Figure 3. Total aboveground carbon stock across the study site was 36.8 t ha⁻¹, derived from timber species, MPTS, banana, and litter. Timber species contributed the largest proportion at 50.6%, followed by banana (26.6%), MPTS (20.35%), and litter (2.45%). Among MPTS, enrichment-planted species accounted for 6.7% of total aboveground carbon, reflecting their relatively young age and smaller diameter classes.

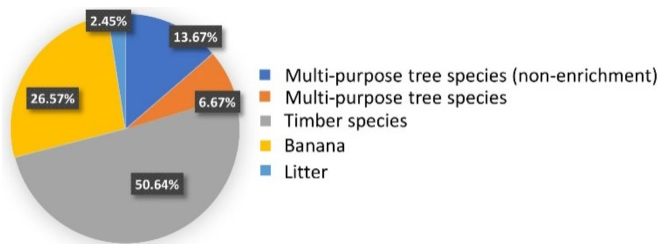

Figure 3. Composition of aboveground carbon stocks among timber species, multi-purpose tree species (MPTS), banana, and litter in the community forest (HKm) of Lantan Village

The variation in carbon stocks among vegetation groups was primarily influenced by differences in diameter distribution, growth form, and stand composition. Timber species contributed more than half of the total aboveground carbon stock despite their relatively low abundance because carbon accumulation increases disproportionately with tree diameter and biomass. In contrast, banana exhibited high population density but contributed a lower proportion of carbon relative to timber species due to its smaller stature and lower biomass per individual. Similarly, enrichment-planted MPTS were concentrated in the smaller diameter classes, limiting their current contribution to total carbon storage.

The observed carbon stock is relatively low when compared with natural forest systems in Lombok. Bae et al. [41] reported aboveground carbon stocks of 109.9 t ha^{-1} for primary forest and 97.8 t ha^{-1} for secondary forest in the West Rinjani Forest Management Unit, while shrub lands stored 26.5 t ha^{-1}. Thus, the carbon stock of HKm Lantan falls between degraded shrub systems and secondary forest, indicating partial recovery but still limited structural development.

Table 3. Aboveground carbon stocks by vegetation group and diameter class (t ha^{-1})

No.	Vegetation Group	DBH >=20 cm	DBH 10-<20 cm	DBH 2-<10 cm	Total	%
1	Multi-purpose tree species (MPTS)	5.03	**2.32**	0.13	7.49	20.35
	- Non-enrichment MPTS	5.03	-	-	5.03	13.67
	- Enrichment MPTS	-	**2.32**	0.13	2.46	6.67
2	Timber species	**15.14**	0.99	**2.51**	**18.64**	**50.64**
3	Banana (*Musa* spp.)	-	-	-	9.78	26.57
4	Litter	-	-	-	0.90	2.45
	Total	20.17	3.31	2.64	36.81	100.00

Note: The highest value within each diameter class and the largest contribution to total carbon stock are shown in bold.

Similar findings have been reported in other community-managed or agroforestry landscapes. Carbon stocks in agroforestry or degraded forest systems may vary widely depending on vegetation structure and land-use history. For example, Sufardi et al. [42] reported aboveground carbon stocks of 69.9 t ha^{-1} in shrub forests and 24.5 t ha^{-1} in shrub lands in sub-optimal dry lands of Aceh Besar, Indonesia. Idris et al. [43] documented an average of 83.7 t ha^{-1} in agroforestry systems in KHDTK Senaru, while Siarudin and Indrajaya [44] found 60 t ha^{-1} of aboveground carbon in *Gmelina arborea* agroforestry systems in West Java. Compared with these systems, the HKm site shows lower carbon storage, largely due to the dominance of short-rotation, low-biomass species such as banana.

The predominance of MPTS and banana in the smaller diameter classes (10–<20 cm and 2–<10 cm) explains the limited carbon accumulation in enriched plots. Most enrichment-planted species have not yet reached substantial diameter growth, resulting in modest contributions to total carbon stocks. In contrast, the larger carbon contributions from timber species originate from individuals that were already present prior to the MCAI enrichment program.

Although the current contribution of enrichment-planted MPTS to aboveground carbon storage remains relatively small, this pattern is closely linked to the young age and limited diameter growth of these trees. Species such as durian (*Durio zibethinus*), avocado (*Persea americana*), and mangosteen (*Garcinia mangostana*) are known to accumulate biomass gradually over long growth periods, suggesting that their contribution to carbon stocks is likely to increase as stands mature. However, the realization of this potential will depend on sustained management practices that allow trees to reach larger diameter classes.

From an ecological perspective, species-diverse agroforestry systems are generally expected to support greater carbon accumulation than simplified systems dominated by a single crop species. This pattern is commonly explained by ecological mechanisms such as functional diversity and niche complementarity, whereby species with different growth forms, canopy structures, rooting depths, and resource-use strategies utilize environmental resources more efficiently than monocultures [25, 26]. As a result, multi-species systems often produce greater total biomass, enhance structural complexity, and maintain more stable ecosystem functioning over time [24, 26]. The integration of MPTS within HKm therefore has the potential to improve long-term carbon sequestration and other ecosystem services as trees mature and occupy different ecological niches within the vegetation structure [23, 24].

Overall, the results indicate that the current vegetation structure constrains carbon storage capacity due to the limited representation of large-diameter woody species. From a management standpoint, promoting the recruitment and retention of long-lived tree species could substantially improve future carbon stocks and strengthen ecosystem resilience within the HKm landscape [18].

3.3 Growth performance of enrichment-planted multi-purpose tree species

Three enrichment-planted MPTS were identified in the study area, namely durian (*Durio zibethinus*), avocado (*Persea americana*), and mangosteen (*Garcinia mangostana*). Measurements of diameter and height for these species are summarized in Table 4. Durian and avocado displayed comparable growth performance, with mean diameters of 11.6 cm and 12.4 cm and mean heights of 8.1 m and 9.5 m, respectively. In contrast, mangosteen exhibited considerably smaller dimensions, reaching a mean diameter of only 5.0 cm and a height of 4.3 m. This difference reflects the slower early growth characteristics of mangosteen relative to other enrichment-planted species.

Table 4. Mean diameter, height, abundance, and density of enrichment-planted multi-purpose tree species (MPTS)

No.	Species	Mean Diameter (cm)	Mean Height (m)	Number of Individuals (33 Plots)	Density (Individuals ha^{-1})
1	Durian (*Durio zibethinus*)	11.6	8.1	84	65
2	Avocado (*Persea americana*)	12.4	9.5	24	18
3	Mangosteen (*Garcinia mangostana*)	5.0	4.3	2	1

The observed diameter and height values indicate moderate early growth performance for durian and avocado under the HKm management system, whereas mangosteen exhibited slower growth, consistent with its physiological characteristics as a late-maturing species. Durian was the most frequently planted enrichment species, with 84 individuals recorded across 33 plots, suggesting strong farmer preference as well as relatively higher establishment and survival rates compared with other species.

Comparisons with previous studies provide additional context for interpreting these patterns. Haba et al. [45] reported that six-year-old mangosteen grown under irrigated lowland conditions attained mean diameters of 7.12 cm and heights of 4.2 m, while individuals growing on forest soils reached 5.45 cm in diameter and 2.8 m in height. Growth values observed in the present study fall within this reported range, indicating that mangosteen performance under mixed agroforestry management in HKm Lantan remains within expected limits.

A similar correspondence is observed for avocado. Biazin et al. [46] documented avocado heights ranging from 10.1 to 17.6 m across different age classes and land-use types in coffee-based agroforestry systems in southern Ethiopia. The mean height recorded in HKm Lantan (9.5 m) is slightly lower but remains consistent with early- to mid-stage growth trajectories in comparable agroforestry environments.

Taken together, these results suggest that enrichment-planted durian and avocado are establishing satisfactorily, although their current contribution to carbon accumulation remains limited by age and size. As trees progress into larger diameter classes, their role in carbon storage is expected to increase, provided that management practices allow long-term retention. Mangosteen, despite slower early growth, may still offer long-term ecological and economic benefits characteristic of high-value tropical fruit trees. Continued monitoring will therefore be necessary to evaluate survival, growth dynamics, and the cumulative contribution of enrichment-planted species to ecosystem carbon stocks over time.

4. CONCLUSIONS

This study demonstrates that vegetation structure in the HKm of Lantan Village is strongly shaped by farmer management practices, particularly the preference for fast-growing and economically valuable species. Although a relatively diverse assemblage of timber species, MPTS, and understory vegetation was recorded, the vegetation structure remained dominated by short-rotation species, while timber species and enrichment-planted MPTS occurred at lower densities, particularly in larger diameter classes.

Enrichment-planted MPTS were mainly distributed within small to medium diameter classes, reflecting their relatively young age and limited structural development. As a result, their current contribution to aboveground carbon storage remains modest. The mean aboveground carbon stock of 36.8 t ha^{-1} was primarily derived from timber species, followed by banana, MPTS, and litter, indicating that carbon storage is still largely dependent on pre-existing woody vegetation rather than recent enrichment plantings. These findings provide a medium-term evaluation of MPTS enrichment outcomes in an HKm landscape seven years after implementation. The results indicate that the successful establishment of enrichment-planted MPTS does not necessarily translate into substantial carbon accumulation in the short to medium term, highlighting the importance of long-term monitoring for assessing restoration effectiveness in social forestry programs.

Overall, the current vegetation structure and the limited presence of large-diameter tree species constrain the present carbon storage capacity of the HKm system. From a management perspective, increasing the retention and growth of long-lived woody species—including enrichment-planted MPTS—while gradually reducing excessive banana density could enhance ecological functions, improve long-term carbon sequestration, and strengthen the sustainability of community-based forest management in the study area.

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REFERENCES

[1] Kendie, G., Addisu, S., Abiyu, A. (2021). Biomass and soil carbon stocks in different forest types, Northwestern Ethiopia. International Journal of River Basin Management, 19(1): 123-129. https://doi.org/10.1080/15715124.2019.1593183

[2] Andrade, E.M., Guerreiro, M.J.S., Palacio, H.A.Q., Campos, D.A. (2020). Ecohydrology in a Brazilian tropical dry forest: Thinned vegetation impact on hydrological functions and ecosystem services. Journal of Hydrology: Regional Studies, 27: 100649. https://doi.org/10.1016/j.ejrh.2019.100649

[3] Zhang, J., Bruijnzeel, L.A., Quinones, C.M., Tripoli, R., Asio, V.B., van Meerveld, H.J. (2019). Soil physical characteristics of a degraded tropical grassland and a 'reforest': Implications for runoff generation. Geoderma, 333: 163-177. https://doi.org/10.1016/j.geoderma.2018.07.022

[4] Karyon, E.Y., Roslinda, E., Riyono, J.N. (2016). The public revenue from the non wood forest product around the area of Raya Nature Preserve in the Village of Nyarumkop District of East Singkawang. Jurnal Hutan Lestari, 4(3): 314-321. https://jurnal.untan.ac.id/index.php/jmfkh/article/view/16169.

[5] Misbahuzzaman, K., Smith-Hall, C. (2015). Role of forest income in rural household livelihoods: The case of village common forest communities in the Chittagong Hill Tracts, Bangladesh. Small-scale Forestry, 14: 315-330. https://doi.org/10.1007/s11842-015-9290-1

[6] Markum, Ichsan, A.C., Saputra, M., Lestari, A.T., Anugrah, G. (2021). The patterns of agroforestry: The implementation and its impact on local community income and carbon stock in Sesaot Forest, Lombok, Indonesia. IOP Conference Series: Earth and Environmental Science, 917(1): 012043. https://doi.org/10.1088/1755-1315/917/1/012043

[7] Bremer, L., Farley, K.A., Chadwick, O.A., Harden, C.P. (2016). Changes in carbon storage with land

management promoted by payment for ecosystem services. Environmental Conservation, 43(4): 397-406. https://doi.org/10.1017/S0376892916000199
[8] Wheeler, C.E., Omeja, P.A., Chapman, C.A., Glipin, M., Tumwesigye, C., Lewis, S.L. (2016). Carbon sequestration and biodiversity following 18 years of active tropical forest restoration. Forest Ecology and Management, 373: 44-55. https://doi.org/10.1016/j.foreco.2016.04.025
[9] Nijmeijer, A., Lauri, P.E., Harmand, J.M., Saj, S. (2019). Carbon dynamics in cocoa agroforestry systems in Central Cameroon: Afforestation of savannah as a sequestration opportunity. Agroforestry Systems, 93: 851-868. https://doi.org/10.1007/s10457-017-0182-6
[10] Kaskoyo, H., Mohammed, A., Inoue, M. (2017). Impact of community forest program in protection forest on livelihood outcomes: A case study of Lampung Province, Indonesia. Journal of Sustainable Forestry, 36(3): 250-263. https://doi.org/10.1080/10549811.2017.1296774
[11] De Royer, S., Van Noordwijk, M., Roshetko, J.M. (2018). Does community-based forest management in Indonesia devolve social justice or social costs? International Forestry Review, 20(2): 167-180. https://doi.org/10.1505/146554818823767609
[12] Solomon, N., Birhane, E., Tadesse, T., Treydte, A.C., Meles, K. (2017). Carbon stocks and sequestration potential of dry forests under community management in Tigray, Ethiopia. Ecological Processes, 6: 20. https://doi.org/10.1186/s13717-017-0088-2
[13] Nurrochmat, D.R., Massijaya, M.Y., Jaya, I.N.S., Abdulah, L., Ekayani, M., Astuti, E.W., Erbaugh, J.T. (2019). Promoting community forestry to reduce deforestation surrounding Gunung Rinjani National Park in Central Lombok, Indonesia. IOP Conference Series: Earth and Environmental Science, 285(1): 012014. https://doi.org/10.1088/1755-1315/285/1/012014
[14] Wahyu, A., Suharjito, D., Darusman, D., Syaufina, L. (2020). The development of community-based forest management in Indonesia and its contribution to community welfare and forest condition. IOP Conference Series: Earth and Environmental Science, 528(1): 012037. https://doi.org/10.1088/1755-1315/528/1/012037
[15] Moktan, M.R., Norbu, L., Choden, K. (2016). Can community forestry contribute to household income and sustainable forestry practices in rural area? A case study from Tshapey and Zariphensum in Bhutan. Forest Policy and Economics, 62: 149-157. https://doi.org/10.1016/j.forpol.2015.08.011
[16] Ministry of Environment and Forestry (KLHK). (2022). Operational plan for Indonesia's FOLU Net Sink 2030. Ministry of Environment and Forestry. https://planologi.kehutanan.go.id/assets/img/publication/BUKU_RENOPS_FOLU_NETSINK_2030_(English).pdf.
[17] Musyoki, J.K., Mugwe, J., Mutundu, K., Muchiri, M. (2016). Factors influencing level of participation of community forest associations in management forests in Kenya. Journal of Sustainable Forestry, 35(3): 205-216. https://doi.org/10.1080/10549811.2016.1142454
[18] Murniati, Suharti, S., Minarningsih, Nuroniah, H.S., Rahayu, S., Dewi, S. (2022). What makes agroforestry a potential restoration measure in a degraded conservation forest? Forests, 13(2): 267. https://doi.org/10.3390/f13020267
[19] Hariyadi, A.R.S., Puroso, P., Ismail, T., Nurhamidi, Mirza, E., Kaemal, Indrawan. (2022). Community contribution to ecosystem restoration in Giri Mulyo Village as a role model of Kerinci Seblat National Park, Jambi-Sumatra, Indonesia. IOP Conference Series: Earth and Environmental Science, 950(1): 012068. https://doi.org/10.1088/1755-1315/950/1/012068
[20] Novasari, D., Wulandari, C., Harianto, S.P., Febryano, I.G., Bakri, S., Kaskoyo, H. (2023). Community preferences for agroforestry patterns in supporting future forestry development. IOP Conference Series: Earth and Environmental Science, 1133(1): 012066. https://doi.org/10.1088/1755-1315/1133/1/012066
[21] Qurniati, R., Febryano, I.G., Zulfiani, D. (2017). How trust influence social capital to support collective action in agroforestry development? Biodiversitas Journal of Biological Diversity, 18(3): 1201-1206. https://doi.org/10.13057/biodiv/d180344
[22] Wanderi, Qurniati, R., Kaskoyo, H. (2019). The contribution of agroforestry to farmers' income and welfare. Jurnal Sylva Lestari, 7(1): 118-127. https://doi.org/10.23960/jsl17118-127
[23] Abebaw, S.E., Yeshiwas, E.M., Feleke, T.G. (2025). A systematic review on the role of agroforestry practices in climate change mitigation and adaptation. Climate Resilience and Sustainability, 4(2): e70018. https://doi.org/10.1002/cli2.70018
[24] Sharma, R., Mina, U., Kumar, B.M. (2022). Homegarden agroforestry systems in achievement of Sustainable Development Goals: A review. Agronomy for Sustainable Development, 42: 44. https://doi.org/10.1007/s13593-022-00781-9
[25] Sollen-Norrlin, M., Ghaley, B.B., Rintoul, N.L.J. (2020). Agroforestry benefits and challenges for adoption in Europe and beyond. Sustainability, 12(17): 7001. https://doi.org/10.3390/su12177001
[26] Schuler, H.R., Alarcon, G.G., Joner, F., dos Santos, K.L., Siminski, A., Siddique, I. (2022). Ecosystem services from ecological agroforestry in Brazil: A systematic map of scientific evidence. Land, 11(1): 83. https://doi.org/10.3390/land11010083
[27] Lelamo, L.L. (2021). A review on the indigenous multipurpose agroforestry tree species in Ethiopia: Management, their productive and service roles and constraints. Heliyon, 7(9): e07874. https://doi.org/10.1016/j.heliyon.2021.e07874
[28] Markum, Setiawan, B., Sabani, R. (2015). Hutan kemasyarakatan sebuah ikhtiar mewujudkan hutan lestari masyarakat sejahtera. Balai Pengelolaan Daerah Aliran Sungai Dodokan Moyosari Provinsi Nusa Tenggara Barat. https://eprints.unram.ac.id/26729/.
[29] Nandini, R., Narendra, B.H. (2011). Kajian perubahan curah hujan, suhu dan tipe iklim pada zone ekosistem di Pulau Lombok. Jurnal Analisis Kebijakan Kehutanan, 8(3): 228-244.
[30] Ranesa, L.S.C., Limantara, L.M., Harisuseno, D. (2015). Analisis rasionalisasi jaringan pos hujan untuk kalibrasi hidrograf pada das Babak Kabupaten Lombok Tengah. Jurnal Teknik Pengairan: Journal of Water Resources Engineering, 6(1): 46-54. https://jurnalpengairan.ub.ac.id/index.php/jtp/article/view/226.
[31] FAO. (2004). National forest inventory: Field manual.

Rome: Food and Agriculture Organization of the United Nations. https://openknowledge.fao.org/server/api/core/bitstreams/614a9eed-25cf-4c10-a6b7-7f85611565ef/content.

[32] Samek, J.H., Anhar, A., Maimunah, S., Skole, D. (2022). Measuring forest ecosystem services in Aceh Province for inclusion to local forest resource management plans. APN Science Bulletin, 12(1): 90-101. https://doi.org/10.30852/sb.2022.1910

[33] Mueller-Dombois, D., Ellenberg, H. (1974). Aims and Methods of Vegetation Ecology. John Wiley & Sons.

[34] Hairiah, K., Ekadinata, A., Sari, R.R., Rahayu, S. (2011). Pengukuran Cadangan Karbon: Dari Tingkat Lahan ke Bentang Lahan 2nd ed. Bogor, World Agroforestry Centre, ICRAF SEA Regional Office, University of Brawijaya (UB), Malang, Indonesia.

[35] Chave, J., Andalo, C., Brown, S., et al. (2005). Tree allometry and improved estimation of carbon stocks and balance in tropical forests. Oecologia, 145: 87-99. https://doi.org/10.1007/s00442-005-0100-x

[36] Hairiah, K., Rahayu, S., Berlian. (2006). Layanan lingkungan agroforestri berbasis kopi: Cadangan karbon dalam biomasa pohon dan bahan organik tanah (studi kasus dari Sumberjaya, Lampung Barat). Agrivita, 28(3): 298-309.

[37] Badan Standarisasi Nasional (BSN). (2011). Measurement and Calculation of Carbon Stocks-Field Measurements for Ground Based Forest Carbon Accounting. Badan Standarisasi Nasional-BSN, Jakarta. https://muspera.kehutanan.go.id/Perpus_search/detail/24132.

[38] Idris, M.H., Latifah, S., Setiawan, B., (2020). Vegetation condition of community-managed forests in Aik Bual Village and Setiling Village, Lombok Island. Jurnal Sylva Lestari, 8(2): 218-229. https://doi.org/10.23960/jsl28218-229

[39] Hidayat, S. (2014). Vegetation conditions in the Sesaot protected forest, West Lombok Regency, West Nusa Tenggara, as basic information for area management. Jurnal Penelitian Kehutanan Wallacea, 3(2): 97-105. https://scholarhub.unhas.ac.id/jpkw/vol3/iss2/4/.

[40] Mansur, M. (2016). Structure and composition tree species in southern of Rinjani Mountain National Park, Lombok, West Nusa Tenggara. Jurnal Biologi Indonesia, 12(1): 87-98. https://www.researchgate.net/profile/Muhammad-Mansur-3/publication/327623197_Jurnal_Biologi_Indonesia_121_Juni_2016/links/5b9a2c1b299bf14ad4d6d592/Jurnal-Biologi-Indonesia-121-Juni-2016.pdf.

[41] Bae, J.S., Kim, C., Kim, Y.S., et al. (2014). Opportunities for implementing REDD+ to enhance sustainable forest management and improve livelihoods in Lombok, NTB, Indonesia. Center for International Forestry Research (CIFOR), Bogor, Indonesia. https://www.cifor-icraf.org/publications/pdf_files/WPapers/WP151Lee.pdf.

[42] Sufardi, S., Syafruddin, S., Arabia, T., Khairullah, K., Umar, H.A. (2022). Comparison of carbon content in soil and biomass in various types of sub-optimal dryland use in Aceh Besar, Indonesia. IOP Conference Series: Earth and Environmental Science, 1116(1): 012049. https://doi.org/10.1088/1755-1315/1116/1/012049

[43] Idris, M.H., Latifah, S., Aji, I.M.L., Wahyuningsih, E., Indriyatno, I., Ningsih, R.V. (2013). Studi vegetasi dan cadangan karbon di Kawasan Hutan Dengan Tujuan Khusus (KHDTK) Senaru, Bayan Lombok Utara. Jurnal Ilmu Kehutanan, 7(1): 47-56. https://doi.org/10.22146/jik.6135

[44] Siarudin, M., Indrajaya, Y. (2017). Carbon stock dynamics of Gmelina (Gmelina arborea Roxb.) based agroforestry in private forest, Tasikmalaya and Banjar District, West Java. Jurnal Wasian, 4(1): 37-46. https://doi.org/10.62142/zsaaqm75

[45] Haba, J.F., Silué, N., Dembele, A., Phaceli, E.D., Koffi, J.K., Letto, A.K. (2024). Reduction of the mangosteen tree (Garcinia mangostana L.) production cycle: Effect of soil type and fertilisers. Bulletin of the National Research Centre, 48: 20. https://doi.org/10.1186/s42269-024-01175-5

[46] Biazin, B., Haileslassie, A., Zewdie, T., et al. (2018). Smallholders' avocado production systems and tree productivity in the southern highlands of Ethiopia. Agroforestry Systems, 92: 127-137. https://doi.org/10.1007/s10457-016-0020-2