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Carbon and biodiversity responses to fire and timber harvesting in dry dipterocarp community forest in Thailand

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Abstract. *Nonthakhot P, Podong C. 2025. Carbon and biodiversity responses to fire and timber harvesting in dry dipterocarp community forest in Thailand. Biodiversitas 26: 5081-5088.* Understanding how burning and harvesting systems in tropical dry forests influence both carbon storage and biodiversity is crucial for sustainable management. This study presents the first landscape-scale assessment of above- and below-ground carbon pools and biodiversity in dry dipterocarp forest managed by community in Thailand under four management regimes: community-based prescribed fire (Ching-Pao), selective harvesting (Ching-Kep), unmanaged natural forest, and wildfire-affected areas. Forty-eight stratified plots (i.e., 12 plots per management regime, each plot measuring 20 × 20 m) were established to measure aboveground biomass, litter biomass, Soil Organic Carbon (SOC), and tree species composition. Prescribed fire plots exhibited the highest aboveground carbon (36.74 ± 2.13 t C/ha) and Shannon diversity index (H′ = 3.21), significantly exceeding wildfire plots (24.11 ± 1.84 t C/ha; H′ = 2.48). SOC was also greatest in prescribed fire plots (38.21 ± 2.87 t C/ha), followed by selective harvesting, unmanaged forest, and wildfire treatments. Beta diversity analysis (Bray–Curtis) revealed distinct community assemblages among treatments, with prescribed fire fostering fire-tolerant species such as *Shorea obtusa* and *Dipterocarpus tuberculatus*. These differences indicate that low-intensity, community-managed burns can enhance carbon sequestration and sustain higher functional and taxonomic diversity compared to unmanaged or severely burned areas. The integration of functional traits—such as thick bark, resprouting ability, and high wood density—appears to underpin the resilience and productivity of fire-managed forests. Overall, the findings provide empirical evidence supporting "fire-smart" community-based forest management as a strategy to align biodiversity conservation with climate mitigation goals in tropical dry forest landscapes.

Keywords: Biodiversity, carbon stock, forest management, prescribed fire, soil organic carbon

INTRODUCTION

Tropical Dry Forests (TDFs) are among the most dynamic and flammable ecosystems in Southeast Asia. In Thailand, Dry Dipterocarp Forests (DDFs) are strongly shaped by frequent low-intensity surface fires, which historically acted as patterned burns that maintained open canopies, promoted regrowth of certain species, and reduced continuous fuel loads (Baker and Bunyavejchewin 2009; Phumsathan et al. 2022). However, shifting fire-suppression policies, combined with land fragmentation, may erode traditional fire knowledge and accelerate landscape degradation (Baker and Bunyavejchewin 2017; Michalko et al. 2024). These shifts can alter vegetation structure and key processes supporting carbon storage and biodiversity, underscoring the need for empirical research in these systems.

Many studies have examined the effects of fire or timber harvesting on carbon and biodiversity separately, but few have assessed both simultaneously across multiple disturbance regimes (e.g., fire and harvesting), particularly in fire-adapted ecosystems such as DDFs. In tropical Asia, research and accounting still emphasize Aboveground Carbon (AGC), while belowground pools—Soil Organic Carbon (SOC) and root biomass—remain underrepresented despite their importance for long-term storage (Matthew et al. 2018; Rozak 2020). Likewise, biodiversity is often evaluated only by species richness, with limited use of functional traits or beta-diversity metrics that better predict post-disturbance trajectories (Schreven et al. 2018; Michalko et al. 2024). Integrating these dimensions into a single framework would strengthen evaluations of how management interventions shape carbon and biodiversity over time.

In recent years, Thailand has experienced a renewed focus of community forest governance under carbon-based forestry mechanisms such as REDD+ and the Thailand Voluntary Emission Reduction (T-VER) scheme. These initiatives highlight the potential for community-based actions to contribute to national climate and biodiversity targets. Yet, the empirical basis for supporting localized, fire-inclusive forest management practices remains relatively scant. In particular, there is limited understanding of how different disturbance regimes interact with climate stressors and local livelihood needs, despite increasing recognition that such interactions are central to sustainable forest management (Sarira et al. 2022; Michalko et al. 2024; Samphutthanont et al. 2024).

Against this backdrop, we assessed how a dry dipterocarp community forest responds to four management regimes: (i) community-based prescribed fire (PF; locally Ching-Pao), (ii) selective harvesting without fire (PH; Ching-Pao), (iii) unmanaged natural forest (C), and (iv) wildfire-affected areas (WF). We examined their effects on Aboveground Biomass and Carbon (AGB, AGC), Soil Organic Carbon (SOC), root biomass, and tree diversity. We hypothesized that PF would produce higher AGC and SOC and a more fire-tolerant community than C and WF, with PH showing intermediate responses. Under Thailand's changing climate, clarifying these impacts is critical to sustaining carbon stocks, biodiversity, and livelihoods when safeguards are applied.

Finally, integrating local knowledge with scientific monitoring strengthens adaptive management. Traditional fire practices—guided by seasonal and ecological cues—can complement modern carbon frameworks like T-VER and REDD+, aligning carbon mitigation with biodiversity conservation. This synergy enhances Thailand's community forestry efforts and supports long-term sustainability in dry forest landscapes. Ultimately, the findings provide guidance for balancing carbon sequestration, biodiversity, and livelihoods, reinforcing DDFs as key natural assets in Thailand's transition toward a low-carbon, climate-resilient future.

MATERIALS AND METHODS

Study area

This study was conducted in the Ban Pak Thap Community Forest (17°43′N, 100°04′E), Uttaradit Province, Northern Thailand (Figure 1). The forest spans ~16,720 ha at 200-450 m a.s.l. on gently undulating terrain under a tropical monsoon climate. Long-term regional observations indicate a mean annual rainfall of ~1,300-1,500 mm (rainy season May-October), a mean annual temperature of ~26.5 °C (range ~14-38 °C), and a mean relative humidity of ~70-80%. Soils are predominantly sandy-loam with low organic matter and a pronounced dry-season moisture deficit. Vegetation is Dry Dipterocarp Forest (DDF) with discontinuous canopies dominated by Dipterocarpaceae (e.g., *Dipterocarpus tuberculatus*, *Shorea obtusa*, *S. siamensis*), co-occurring deciduous trees (e.g., *Xylia xylocarpa* var. *kerrii*, *Terminalia* spp.), and a grassy understory (e.g., *Imperata cylindrica*, *Themeda triandra*). The landscape has a long history of recurrent, low-intensity anthropogenic surface fires during the dry season.the dry season.

Experimental design

In this study, four different forest management regimes were analyzed, including (i) unmanaged natural forest as control (C); (ii) annual light burning by the community, locally known as Ching-Pao or prescribed fire (PF); (iii) selective logging without fire, locally called Ching-Pao or prescribed harvesting (PH); and (iv) uncontrolled burning or wildfire (WF). We evaluated four management regimes implemented by the community and/or arising from recent events: prescribed fire (PF; Ching-Pao), selective harvesting without fire (PH; Ching-Pao), unmanaged (C), and wildfire (WF). Below we detail the operational context to support reproducibility (Table 1).

We established 48 plots (20 × 20 m; 12 per regime) using a stratified–random design, with ≥50 m spacing to minimize spatial autocorrelation. To ensure the plots were independent, they were at least 50 m apart to reduce spatial autocorrelation. This choice of number of replicates (n = 3) per treatment was pragmatic given logistical constraints and typical for comparable studies in ecological literature, providing ~80% power to detect moderate effect sizes (Cohen's d ≈ 0.6) under ANOVA. Treatments were applied in March 2023, and all ecological variables were measured one year later to capture first-year post-disturbance responses.

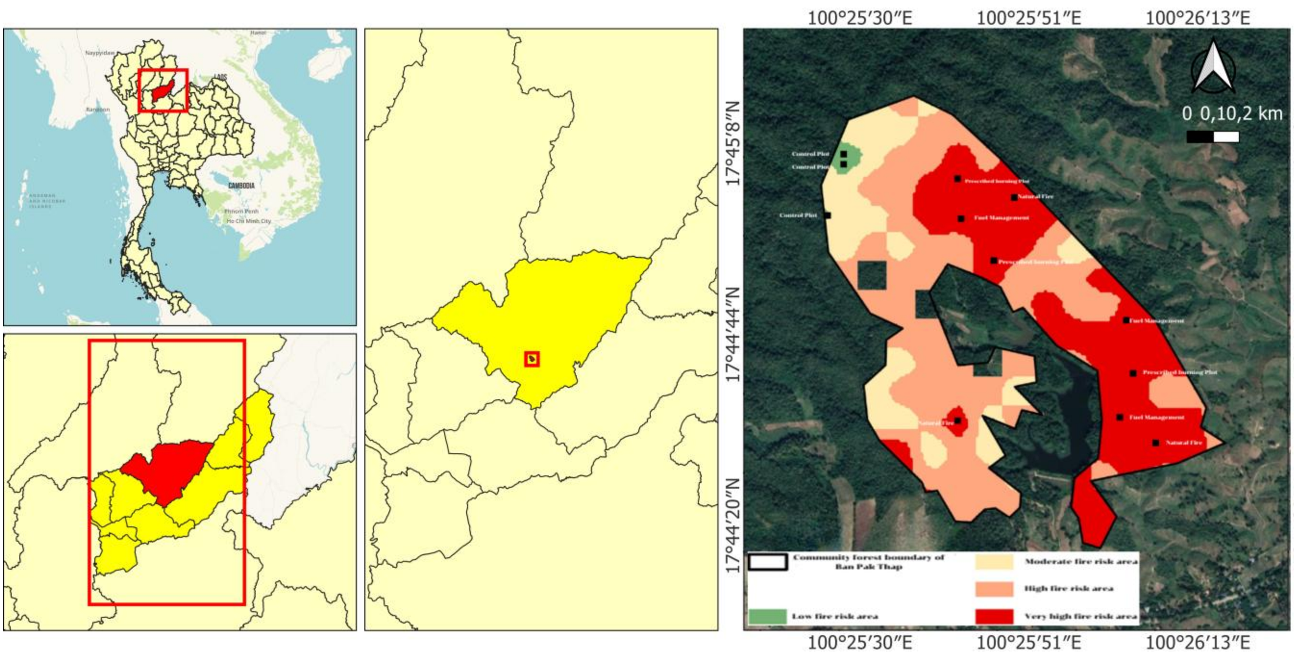

Figure 1. Fire-risk map of the Ban Pak Thap Community Forest, Tha Pla District, Uttaradit Province, Thailand

Table 1. Operational parameters of the four management regimes—prescribed fire (PF; Ching-Pao), selective harvesting without fire (PH; Ching-Kep), unmanaged control (C), and wildfire (WF)—in a dry dipterocarp community forest in Northern Thailand

Regime	Seasonality	Frequency	Spatial unit / extent	Practice	Targets / exclusions	Safeguards & records
PF (Ching-Pao)	Late dry season (Feb-Mar 2023)	Annual (scheduled)	~1-5 ha burn blocks	Backing-fire along 1-2 m control lines; limited head-fire strips	Target fine fuels (cured grasses, leaf litter, twigs); exclude large trees, riparian buffers, seed trees	Weather window: RH ≥ 45-60%, wind ≤ 3 m·s^{-1}; edge patrols; log date/unit/crew
PH (Ching-Pao)	Early dry season (Dec 2022-Jan 2023)	As scheduled	Compartment-based	Selective felling (DBH ≥ 20 cm); retain seed trees & structural legacies	Non-protected deciduous hardwoods (e.g., *Xylia*, *Terminalia* spp.); basal area removal ≤ ~20%	Use existing trails; minimize soil disturbance; log stems/volumes/compartments
C (Unmanaged)	—	—	Plots within intact stands	No intentional intervention	Natural litter & understory development	Patrol only; ≥ 2 years since last intentional treatment
WF (Uncontrolled)	Dry season (Maret-Apr 2023)	Irregular (~2-4 yrs)	Burned polygons ~5-30 ha	Uncontrolled ignition & spread; no control lines	Variable severity; scorch height ~0.5-2 m	Document date, evidence, perimeter; contrast vs PF conditions

Note: PF: Prescribed fire (Ching-Pao), PH: Selective harvesting without fire (Ching-Pao), C: Unmanaged control, WF: Wildfire

Table 2. Summary of carbon measurement protocols

Carbon pool	Measurement method	Equation/Tool	Reference
Aboveground Biomass	DBH (≥4.5 cm), height, wood density	AGB = 0.0509 × ρ × D² × H	Ogawa et al. (1965); Chave et al. (2014)
Litter Biomass	Collected from four 0.5 × 0.5 m subplots; oven-dried	Dry weight averaged, converted to C using factor = 0.47	Standard protocols
Soil Organic Carbon	0-30 cm composite samples; Walkley–Black method	SOC = %C × Bulk density × Soil depth × 0.1	Nelson and Sommers (1996); IPCC (2006)
Root Biomass	Indirect from AGC	Root C = AGC × 0.24	Cairns et al. (1997)

Notes: AGB: Aboveground biomass (t ha^{-1}), AGC: Aboveground carbon (t C ha^{-1}), SOC: Soil Organic Carbon (t C ha^{-1}), ρ: Oven-dry wood density (g cm^{-3}), D: Diameter at breast height at 1.3 m (cm), H: Total tree height (m), CF: Biomass-to-carbon fraction (0.47, unitless), %C: Soil carbon concentration by Walkley–Black (percent by mass), BD: Soil bulk density (g cm^{-3}), z: Soil layer thickness (cm; here 0-30 cm), constant 0.1 converts units to t C ha^{-1} for SOC

Carbon stock assessment

Three major carbon pools were measured: Aboveground Biomass (AGB), litter biomass, and Soil Organic Carbon (SOC). Belowground carbon (root biomass) was estimated using allometric scaling. The methods and equations for calculating carbon stock for each pool were presented in Table 2.

Biodiversity assessment

Within each 20 × 20 m plot, we established two 50-m transects that intersected at the plot center. Canopy height stratum was recorded at evenly spaced grid points along both transects. All woody stems (vascular trees) with diameter at breast height (DBH, 1.3 m) ≥ 5 cm within the plot were identified to species and tallied; twigs and branches were not counted as separate individuals. We calculated the species richness and Shannon-Wiener diversity index (H′). Measurements based on Bray–Curtis dissimilarity and Non-metric Multidimensional Scaling (NMDS) ordination were used to study the beta diversity. We used Indicator Species Analysis (ISA) to determine treatment-specific assemblages and classified species based on regeneration mode, successional status and fire tolerance. Indicator species were identified using the Dufrêne–Legendre Indicator Value statistic (IndVal.g) implemented in the indicspecies package. IndVal combines specificity (A; proportional abundance in the target group) and fidelity (B; frequency of occurrence), and ranges from

0 to 1 (higher values indicate a stronger association). Significance was tested by 999 permutations and p-values were Benjamini–Hochberg–adjusted across taxa.

Statistical analyses

One-way ANOVA was used to investigate the significant difference in terms of AGB, AGC, SOC, and diversity indices across the four treatments (i.e., management regimes). Tukey's HSD was applied post-hoc for pairwise differences. Non-normal data (e.g., species dissimilarity) were analyzed using Kruskal–Wallis and Dunn's test. Effect sizes were reported as η^2 and interpreted per Cohen's conventions, classified as small (0.01), medium (0.06) and large (0.14+).

All statistical analyses were performed in R version 4.2.3. The package vegan was used for NMDS, Bray–Curtis, PERMANOVA analyses, agricolae for ANOVA and Tukey's HSD and indicspecies for Indicator Species Analysis. Prior to parametric tests, assumptions of normality and homogeneity were checked using Shapiro-Wilk and Levene's test, respectively.

RESULTS AND DISCUSSION

Aboveground carbon and litter

Plots managed with prescribed fire had the highest Aboveground Carbon (AGC) and litter carbon. Mean AGC in prescribed-fire plots was 36.74 ± 2.13 t C ha^{-1}, significantly greater than in wildfire-affected plots (24.11 ± 1.84 t C ha^{-1}). Litter carbon mirrored this pattern: prescribed-fire plots stored 4.12 ± 0.24 t C ha^{-1} versus 2.97 ± 0.17 t C ha^{-1} after wildfire. Differences among regimes were significant (ANOVA $F(3,44) = 11.24$, $p < 0.001$; $\eta^2 = 0.43$), indicating a large management effect. Tukey's HSD showed prescribed fire > unmanaged and wildfire, with no significant difference between prescribed fire and prescribed harvesting. The full set of AGB, AGC, litter carbon, and CO_2-equivalents by regime is summarised in Table 3.

Soil organic carbon and root biomass

The pattern for aboveground data as presented above agreed well with belowground observation. Similar differences were also confirmed by the trends between mean statistics on Soil Organic Carbon (SOC) and root biomass carbon. However, where these data pointed to the existence of different trends in the two soils (Figure 2). SOC content was different between the prescribed fire and wildfire plots (38.21 ± 2.87 t C/ha and 26.89 ± 1.91 t C/ha respectively; Table 4. Root carbon, estimated to be 24% of the AGC (8.82 ± 0.53 t C/ha in prescribed fire plots; Table 4), followed this pattern too. Again, the statistical results were significant ($F(3,44) = 13.56$, $p < 0.001$) but with an even more prominent effect size ($\eta^2 = 0.48$), underlining clear differences in management regime impact on belowground carbon (BGC) across the study sites. In addition, there was a very significant and robust positive correlation between AGC and root carbon (I = 0.96, $p < 0.001$), showing that aboveground biomass can be used to accurately predict belowground carbon in those forests. Table 4 gives detailed comparisons of SOC and root carbon stocks, together with their 95% confidence intervals (CI). Figure 3 plots variation in SOC levels according to management regimes, making it clear that prescribed fire is far and away the most effective means of conserving soil carbon.

Species richness and alpha diversity

Across regimes, prescribed fire showed the highest Shannon–Wiener diversity (H′ = 2.47, 95% CI [2.34, 2.59]), followed by prescribed harvesting (H′ = 2.33, [2.22, 2.44]) and the unmanaged control (H′ = 2.11, [2.02, 2.20]). Wildfire-affected areas had the lowest diversity (H′ = 1.92, [1.84, 2.00]). Differences among regimes were significant (ANOVA $F(3,44) = 8.92$, $p < 0.001$; $\eta^2 = 0.37$); Tukey groupings are reported in Table 5.

Table 3. Synthesis of key ecological metrics by management regime: AGB (t/ha), AGC (tC/ha), CO_2-eq (t/ha), Litter carbon (t C/ha), and SOC

Management regime	AGB (t/ha)	AGC (tC/ha)	CO_2-eq (t/ha)	Litter carbon (t C/ha)
Prescribed fire (Ching-Pao)	78.17 ± 4.53	36.74 ± 2.13	134.72 ± 7.81	4.12 ± 0.24
Prescribed harvesting (Ching-Kep)	71.53 ± 5.08	33.62 ± 2.39	123.42 ± 8.78	3.74 ± 0.28
Unmanaged forest	61.47 ± 4.27	28.89 ± 2.01	106.01 ± 7.37	3.31 ± 0.21
Wildfire-affected area	51.30 ± 3.91	24.11 ± 1.84	88.49 ± 6.76	2.97 ± 0.17

Note: Values are mean ± 95% CI (n = 12 per regime)

Table 4. Soil organic carbon and root carbon under different forest management regimes

Management regime	SOC (t C/ha)	Root C (t C/ha)*	Total Belowground C (t C/ha)
Prescribed fire (Ching-Pao)	38.21 ± 2.87	8.82 ± 0.53	47.03 ± 3.05
Prescribed harvesting (Ching-Kep)	34.62 ± 2.43	8.07 ± 0.57	42.69 ± 2.83
Unmanaged forest	31.54 ± 2.22	6.93 ± 0.48	38.47 ± 2.54
Wildfire-affected area	26.89 ± 1.91	5.79 ± 0.43	32.68 ± 2.17

Note: *: Root carbon was estimated as 24% of AGB-derived carbon (AGC) using conversion factors from Cairns et al. (1997)

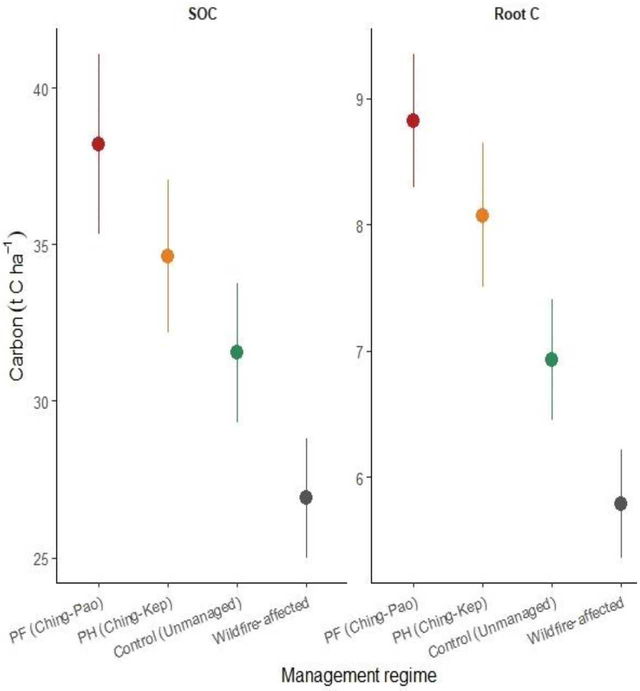

Figure 2 . Belowground carbon pools by management regime. Points show mean stocks (t C ha^{-1}) with 95% confidence intervals for Soil Organic Carbon (SOC) and root carbon. n = 12 per regime

Table 5. Alpha diversity by management regime: Shannon–Wiener index (H′) with 95% confidence intervals. Values are means (n = 12 per regime). Shared letters indicate no significant difference (Tukey HSD, α = 0.05). No β-diversity metrics are included

Management regime	H′ (mean)	95% CI	Significance group
Prescribed fire (Ching-Pao)	2.47	[2.34, 2.59]	a
Prescribed harvesting (Ching-Pao)	2.33	[2.22, 2.44]	ab
Unmanaged forest (Control)	2.11	[2.02, 2.20]	bc
Wildfire-affected area	1.92	[1.84, 2.00]	c

Note: Diversity indices were calculated using the Shannon–Weiner formula. Statistical differences among regimes were determined using one-way ANOVA followed by Tukey's HSD test (α = 0.05). Values sharing the same letter are not significantly different ($p > 0.05$)

Beta diversity and species composition

Species composition differed significantly among management regimes. This reflected contrasting successional trajectories and ecological processes. PERMANOVA based on Bray–Curtis dissimilarities detected significant among-regime differences (Table 6; cf. Bray and Curtis 1957), with the largest pairwise separation generally observed between prescribed fire and wildfire. Consistently, the NMDS ordination showed partial separation by regime (stress = 0.12), with prescribed-fire plots tending to shift along NMDS1 while still overlapping to some extent with other regimes (Figure 3). Taken together, these results indicate that low-intensity prescribed fire helps maintain pyrophytic dipterocarp assemblages, whereas severe wildfire or long-term neglect is associated with a relative decline of those assemblages and a greater representation of disturbance-tolerant or shade-tolerant taxa (see indicator species in Table 7).

PERMANOVA analysis gave similar findings, demonstrating that all pairs of regimes were significantly different ($p < 0.05$). Values for R^2 ranged from 0.16 to 0.27 and indicated moderate effect sizes of fire and harvesting management methods. Indicator Species Analysis showed that the management regimes are distinguished by different species associations. For example, *S. obtusa* and *D. tuberculatus* were significant indicator species of prescribed-fire plots (Dufrêne–Legendre Indicator Value, IndVal.g = 0.42 on a 0-1 scale; BH-adjusted $p < 0.05$), consistent with adaptation to surface fires. In contrast, *Sindora siamensis* and *X. xylocarpa* were associated with prescribed-harvesting plots (IndVal.g = 0.37), likely reflecting greater light and canopy gaps. Unmanaged forests contained shade-tolerant genera (e.g., *Canarium subulatum*), whereas disturbance-tolerant species (e.g., *Cassia siamea*, *Lagerstroemia calyculata*) dominated wildfire plots (Table 7). Taken together, these results hint that prescribed fire fosters something completely different from either unmanaged forest or wildfire regime. If dry dipterocarp forests are managed using controlled burning and selective harvesting, both biodiversity and ecosystem resilience can be enhanced.

Unambiguously, the results suggest that in community forest, low intensity prescribed burning and prescribed timber harvesting sequester more carbon and contain higher biodiversity values than unmanaged and wildfire-affected forests. In contrast, wildfire plots always had the lowest values – for both carbon and diversity metrics. This indicates that some level of moderate, planned disturbance is conducive not only to maintaining ecological function but perhaps also enhancing resilience in fire-adapted dry forest ecosystems.

Table 6. The matrix of Bray–Curtis Dissimilarity and PERMANOVA analysis

Regime Pairwise	Bray–Curtis Dissimilarity	PERMANOVA R^2	p-value
Prescribed fire vs Wildfire	0.63	0.268	0.001
Prescribed fire vs Prescribed harvest	0.41	0.178	0.012
Prescribed fire vs Unmanaged	0.49	0.212	0.004
Prescribed harvest vs Wildfire	0.52	0.195	0.003
Prescribed harvest vs Unmanaged	0.38	0.161	0.028
Unmanaged vs Wildfire	0.44	0.184	0.006

Note: Based on 999 permutations. All pairwise comparisons were significant at α = 0.05

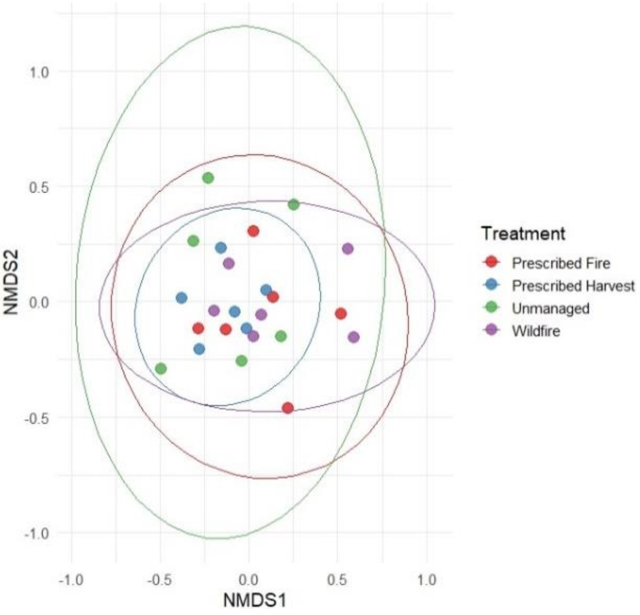

Figure 3. NMDS ordination (Bray–Curtis) of tree community composition by management regime. Points are plots colored by regime. Ordination is used for visualization; group differences are tested with PERMANOVA (Table 6). Partial overlap among point clouds is expected and does not preclude statistically significant differences

Table 7. Indicator species by management regime (Dufrêne–Legendre IndVal.g, 0-1 scale) with BH-adjusted p-values. Only taxa with IndVal.g ≥ 0.25 and adjusted $p < 0.05$ are reported

Management regime	Indicator species	Mean IV score
Prescribed fire	*Shorea obtusa*, *Dipterocarpus tuberculatus*	0.42
Prescribed harvesting	*Sindora siamensis*, *Xylia xylocarpa*	0.37
Unmanaged forest	*Canarium subulatum*, *Terminalia mucronata*	0.33
Wildfire	*Cassia siamea*, *Lagerstroemia calyculata*	0.31

Note: Only species with IV > 0.25 and $p < 0.05$ are shown

Discussion

Our findings provide compelling evidence that fire-adapted management systems in Dry Dipterocarp Forests (DDFs) can substantially influence ecosystem functions, especially in terms of carbon accumulation and biodiversity dynamics. Prescribed fire (Ching-Pao) showed the highest levels of aboveground biomass and Soil Organic Carbon (SOC), suggesting that low-intensity, controlled burns may enhance carbon sequestration over time (Penboon et al. 2023); (Phumsathan et al. 2022). This aligns with findings from Feng et al. (2024), who revealed that root-derived carbon inputs have stronger control over soil microbial communities and ecosystem multifunctionality than aboveground litter inputs, thereby influencing SOC stabilization and belowground carbon cycling. The restoration plots supported tree species with thick bark, resprouting capability, and fine-root proliferation—traits commonly associated with resilience in fire-prone environments (Chaiyo et al. 2011; Duangon et al. 2024). Such functional traits not only shape species composition but also influence carbon inputs via litter quality and root turnover, in turn modifying SOC pools (Toda et al. 2007; Hartoyo et al. 2019). Beta diversity patterns and PERMANOVA results indicate that the two of fire effects on community composition are significantly different for each management regime; no single treatment can be seen as representing an intermediate state between other two treatments. Static variation in NMDS ordination and Bray–Curtis dissimilarities is particularly active between prescribed fire and wildfire plots. This suggests that disturbance intensity and frequency combine to create an environmental filter (Wiriya and Kaitpraneet 2009; Phosri et al. 2012). Notably, the highest species richness and evenness each occurred under prescribed fire which implies a delicate relationship between disturbance and regeneration that keeps the ecosystem as a whole stable (Thammanu et al. 2021; Phumsathan et al. 2022). These observations are consistent with Gough et al. (2024), who argued that intermediate disturbance promotes species coexistence and carbon cycling processes. Finally, indicator species analysis revealed that *S. obtusa* and *X. xylocarpa* were significantly associated with high SOC and resilient regimes. These species have ecological traits such as deep rooting systems, high wood density and drought tolerance, which improve carbon permanence and structural resilience (Hartoyo et al. 2019; de Aguiar-Campos et al. 2021).

This trend is more strongly supported by findings from Southeast Asia and other dry tropical forest ecosystems. The functional traits such as wood density, SLA, or leaf thickness have been very important for determining how communities might influence carbon storage in various fire regimes. So, trait diversity among wood density and SLA was strongly linked to aboveground soil carbon increases in dry dipterocarp forest edges in Northern Thailand (Asanok et al. 2021). Similarly, trait responses to fire and forest edge effects in savanna landscapes showed that fire frequency led to significant shifts in structural biomass and trait convergence, suggesting resilience thresholds in frequently disturbed systems (Armenteras-Pascual et al. 2025). More regionally, carbon storage was dramatically different between disturbed and undisturbed parts of the dry dipterocarp forests in Thailand, underlining an ecological cost of undisturbed disturbances (Phumphuang et al. 2025). Furthermore, the transformation of dry dipterocarp forests into dry evergreen forests, often caused by fire suppression, has been shown to change food web structure and species interactions in ways that reduce ecological specialization and may lead to increasingly variable trophic dynamics (Michalko et al. 2024). Some species, such as dipterocarp, have been found to be better suited for particular locations. If restoration is carried out to this purpose, it can improve both local ecology and provide a foundation for future land use: this is one result of the journey taken by Phetcharaburanin et al. (2020) and Thichan et al. (2020). Other examples demonstrate how disturbing frequency also shapes the passing on of carbon.

Areas of combustion at intermediate intensity always showed higher aboveground biomass and more species; while frequent huge forest burning sashes years of carbon retained in trees that would otherwise have been released (Ray et al. 2022). These findings are in line with ecosystem theory: ecosystems under minor disturbances that recur often throughout several lessons may develop stronger buffered functional characteristics than those hit by more overwhelming or infrequent events (Baker et al. 2023).

These lines of evidence further confirm the assertion of long-term ecological benefits associated with prescribed fire and help to throw the emphasis on managing for functional traits diversity rather than just planting trees. Future efforts will need to pay attention to long-term monitoring, trait-based metrics and adaptive frameworks that ease ecological theory with community forest practices.

In conclusion, carbon storage and species conservation are greatly enhanced when fire-adapted ecological management - especially where controlled burning is the order of the day - is carried out in dry dipterocarp forests. Biomass, SOC, species evenness, etc. increased substantially under prescribed fire regimes. These eventual trends increased responsibility for the aboveground community structure probably reflect the environment's devastating impact on ecosystem functions, as evidenced by heavier basal areas in the present than either pre- or post-disturbance. These attributes are functional traits that made resilient forest communities possible and reflect the role of environmental filtering. Variation in beta diversity and indicator species also clearly indicates different processes of community assembly under different disturbance regimes. Taken together, these results suggest that ecological management based on functional attributes has the potential to both conserve biodiversity and increase carbon fixation. For conservation and policy, our results call for more flexible, community-based forest management approaches that recognize the value of ecological theory. Incorporating long-term monitoring and restoration planning based on functional traits will be crucial for sustaining both carbon processes and ecosystem resilience in future climate scenarios.

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