Plant Functional Traits and the Factors Determining Regeneration Affecting of Forest Tree Species Reestablish Ability in Uplands Restoration Practice, Northern Thailand

Lamthai Asanok[1*], Dokrak Marod[2], Prateep Duengkae[2], Umpron Pranmongkol[3], Hiroko Kurokawa[4] Masahiro Aiba[4], Masatoshi Katabuchi[4] and Tohru Nakashizuka[4]

[1] Department of Agroforestry, Maejo University, Phrae Campus, Phrae 54140
[2] Department of Forest Biology, Faculty of Forestry, Kasetsart University, Bangkok 10900
[3] National Park Division, Department of National Park, Wildlife and plant Conservation, Bangkok 10900
[4] Graduate School of Life Sciences, Tohoku University, Aobayama, Aoba-ku, Sendai 980-8578, Japan
*Corresponding author, E-mail: lamthainii@hotmail.com

Abstract

We investigated plant functional traits and the factors affecting restoration success in forest communities that had been restored both by natural regeneration and enrichment plantations, in abandoned shifting-cultivation areas within the tropical montane forests of Suthep-Pui National Park Chiang Mai, northern Thailand. Five 1-ha permanent plots (100 m × 100 m) were established in three different forest management areas: primary forest, secondary forest, and enrichment plantations. The species composition of canopy trees, regenerated seedlings, and saplings were analyzed to determine tree functional traits and the factors governing forest composition. We found that trees within primary forest tended to have relatively heavier wood and larger seeds than secondary forest species. The dominance of certain species in primary forests was significantly correlated with wood density and seed size, although the correlations in secondary forests and enriched plantations varied among stands. The seedlings of the species with high leaf toughness, large leaf mass area, and wood density tended to be more sensitive to environmental conditions. Results suggest that the restoration of primary forest by natural regeneration is difficult because it is prevented by both environmental conditions and recruitment limitation. The contribution of these factors was species-dependent, which could be partly predicted by their functional traits.

Introduction

Forest restoration, defined as the process of assisting the recovery of a forest ecosystem that has been degraded, damaged, or destroyed, is an intentional activity that initiates or accelerates the recovery of a forest ecosystem with respect to its health, integrity, and sustainability (Mansourian, 2005). Restoration following secondary succession is sometimes prohibited by environmental conditions and/or recruitment limitation (Bohnke et al., 2012). Species assemblies at such sites may depend on both biotic interactions and environmental filtering acting over ecological timescales. Plant functional traits are often used as proxies to determine whether species have different ecological strategies for reproduction and resource capture (Cornelissen et al., 2003). Approaches based on functional traits have been used to demonstrate the importance of environmental filtering in the structure of diverse ecological communities (Paine et al., 2011). Thus, information regarding functional traits could be utilized in restoration practices. In northern Thailand, most of the mountainous areas had disturbed by shifting cultivation, and large areas of degraded

forestland require urgent restoration. A new approach to conserve biodiversity has subsequently become the top priority in restoration management. However, few evaluations have been made of species functional traits and the factors affecting the restoration process. Our study investigated forest communities that had been restored both by natural regeneration and enrichment plantation, considering plant functional traits and the factors affecting restoration success after the abandoned of shifting cultivation in tropical montane forests.

Methodology

This study was undertaken in central Suthep-Pui National Park ($18^{o}47'–18^{o}50'$N, $98^{o}53'–98^{o}55'$E), which is situated 1,265–1,500 m above mean sea level on Mount Pui, northern Thailand. Originally, the study site had been covered with lower tropical montane forest. Five study sites were selected. The first was in a typical primary forest (PF) in the Kog Ma Experimental Watershed area. The next two were in secondary forests, which had been cultivated and then abandoned approximately 30 years previously: an abandoned area far from villages in an area that had not been disturbed after abandonment (AFV) and an abandoned area near a village where people still collected non-timber forest products (ANV). The final two sites were in enrichment plantation forests: a plantation of mixed species (PMS) and a plantation of one species (PPS). For each site, we established a 1-ha (100 m × 100 m) permanent plot, which was divided into 10 m × 10-m quadrats, generating a total of 100 quadrats. At the corner of each 10 m × 10-m quadrat, we established a 2 m × 2-m sub-quadrat generating a total of 100 sub-quadrats per site. We enumerated adult trees [diameter at breast height (DBH) ≥ 2 cm] in every 10 m × 10-m quadrat, and saplings (DBH < 2 cm; height > 1.30 m) and seedlings (height < 1.30 m) in every 2 m × 2-m sub-quadrat. Six functional plant traits were investigated and included in the analysis: leaf mass area (LMA), leaf size, leaf toughness, leaf thickness, wood density, and seed size. We measured light and soil moisture in every sub-quadrat (500 quadrats in total). The values of the functional traits of the species were analyzed by principal components analysis (PCA) and the dominance of a particular species in each plot. To analyze environmental factors (forest structure, physical environment and recruitment limitation), and functional traits affecting regeneration, we applied generalized linear mixed models (GLMMs) for a stepwise regression analysis of seedling/sapling density of species.

Results and Discussion

Species composition and functional traits

Adult trees accounted for 9,955 stems from a total of 167 species. Primary forest tended to have slightly higher values of wood density and seed size than other forests. The trait values of trees growing in secondary plots and enriched plantation varied greatly (Fig. 1). The PCA of functional traits among species explained 63% of their variations cumulatively up to principal component 2. The dominant species in primary forest tended to have high values for functional traits such as leaf toughness, wood density, and seed size (Fig. 2). Some species displayed distinguishing characteristics such as thick leaves in *Bischofia javanica* large leaves in *Toona ciliata* high LMA and tough leaves in *Castanopsis acuminatissima* and dense wood and large seeds in *Castanopsis armata*.

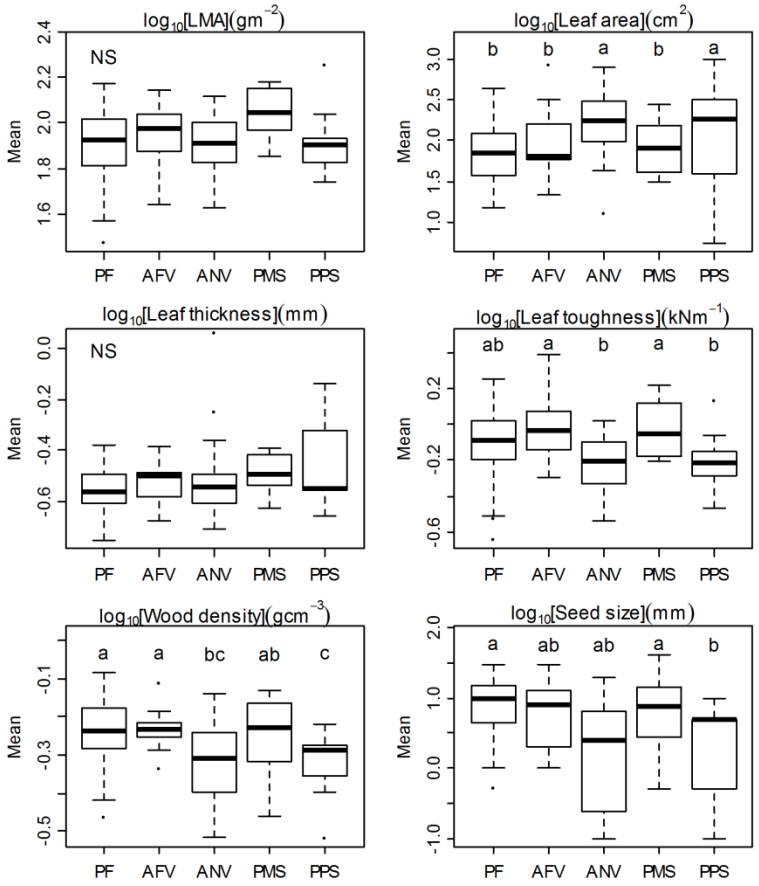

Figure 1 Comparing means of the values for functional traits of each species group; in primary forest (PF), secondary forests [abandoned area far from the village (AFV) and abandoned area near the village (ANV)], and enrichment plantations [plantation of mixed species (PMS) and plantation of one species (PPS)]. The comparison used a one-way ANOVA, with a significant difference at $p < 0.05$

The factors determining tree regeneration

The factors relating to forest type and structure affected the regeneration of seedling/sapling density of many species are show, while those relating to the physical environment (soil and light) affected a relatively small number of species. The recruit limitation of distance from conspecific species had an intermediate effect (Table 1).

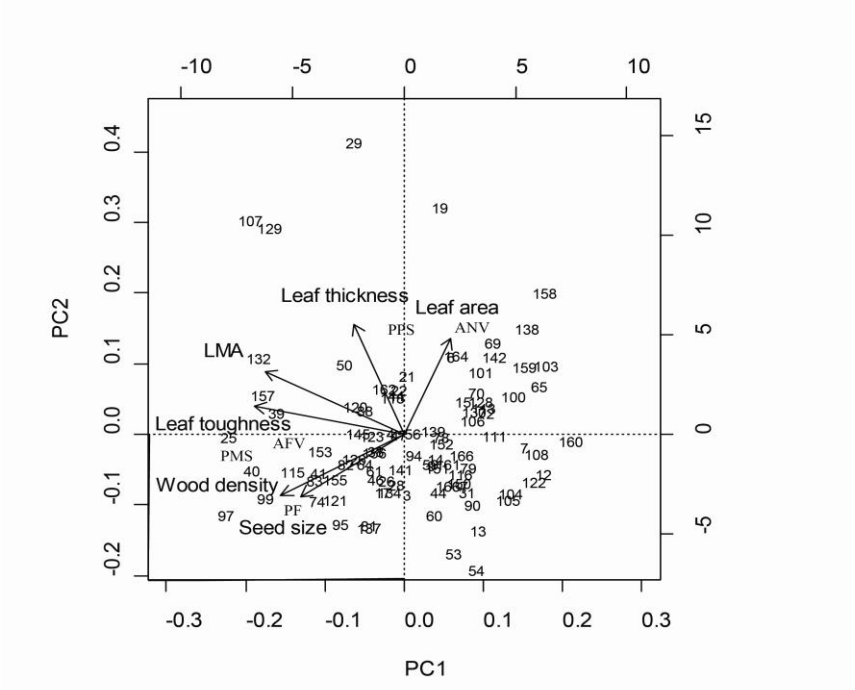

Figure 2 Principal components analysis (PCA) of functional traits affecting tree species in primary forest (PF), secondary forests [abandoned area far from the village (AFV) and abandoned area near the village (ANV)], and enrichment plantations [plantation of mixed species (PMS) and plantation of one species (PPS)]

Table 1 The results of GLMMs showing the factors determining tree regeneration relating to the density of seedlings/saplings with climax species traits and pioneer species traits. D, FT, SMC, RLI, and DM indicate tree density, forest type, soil moisture content, relative light intensity, and distance from conspecific adults, respectively. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

Species	D (stem ha^{-1})	FT	SMC (%)	RLI (%)	DM (m)
	Estim.	Estim.	Estim.	Estim.	Estim.
Beilschmiedia gammieana	-0.014*	0.766**	0.056**	-0.073*	-0.035***
Castanopsis acuminatissima	-0.015*	1.810**	0.021***	-0.075***	-0.091***
Castanopsis tribuloides		1.180***		0.085**	
Cinnamomum iners		1.619***	0.022**		-0.021***
Diospyros glandulosa		0.821**			
Eurya acuminata		-0.861***			
Glochidion eriocarpum				0.032*	
Helicia nilagirica	0.008*				-0.030***
Litsea martabarnica	0.016*	0.724**			
Maesa ramentacea		0.399**	0.056***		-0.020*
Sarcosperma arboreum	0.016*		-0.057***	0.169***	-0.056***
Syzygium claviflorum	-0.014***	1.425***	0.027***	-0.116***	-0.135***

Functional traits affecting tree regeneration

Seedling/sapling abundance for all tree species and at all sites had positive and significant correlations with LMA, seed size, wood density, and leaf toughness, and a negative significant correlation with leaf area. In the primary forest, seedling/sapling abundances were positively correlated with LMA, seed size, wood density, and leaf toughness, and negatively correlated with leaf area and leaf thickness. In secondary forests, seedling/sapling abundance was negatively correlated with LMA and wood density, and positively correlated with leaf thickness and leaf area (Table 2). The functional traits related to seedling/sapling abundance in the primary forest were similar to those for all sites, although fewer traits in secondary forests were related to seedling/sapling abundance. This suggests that tree species in primary forest have traits relating to regeneration but their establishment in secondary forest is difficult, although these species were well established in primary forest. In enrichment plantations were intermediate between primary and secondary forest traits (Table 2).

Table 2 The results of GLMMs showing the functional traits relating to the abundance of seedlings/saplings in all sites, primary forest, secondary forest, enrichment plantations. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$

Functional trait	Seedling abundance			
	All sites *z*-value	Primary forest *z*-value	Secondary forest *z*-value	Enrichment plantations *z*-value
Leaf toughness (kN m^{-1})	3.092**	9.767***		5.276***
Leaf thickness (mm)		–7.498***	4.071***	–5.796***
Wood density (g cm^{-3})	3.647***	6.890***	–2.370*	–2.529*
Leaf area (cm^2)	–7.809***	–10.545***	3.636***	6.037***
LMA (g m^{-2})	8.101***	7.095***	–2.644***	7.453***
Seed size (mm)	11.144***	1.979*		19.646***

References

Bohnke, M., Kreissig, N., Krober, W., Fang, T., Bruelheide, H., 2012. Wood trait–environment relationships in a secondary forest succession in South-East China. Trees – Struct. Funct. 26, 641–651.

Cornelissen, J.H.C., Lavorel, S., Garnier, E., Diaz, S., Buchmann, N., Gurvich, D.E., Reich, P.B., ter Steege, H., Morgan, H.D., van der Heijden, M.G.A., Pausas, J.G., Poorter, H., 2003. A handbook of protocols for standardised and easy measurement of plant functional traits worldwide. Aust. J. Bot. 51, 335–380.

Mansourian, S., 2005. Overview of forest restoration strategies and terms. In: Mansourian, S., Vallauri, D., Dudley., N. (Eds.), Forest Restoration in Landscapes: Beyond Planting Trees. Linking Restoration and Ecological Succession. Springer, New York, pp. 8–13.

Paine, C.E.T., Baraloto, C., Chave, J., Herault, B., 2011. Functional traits of individual trees reveal ecological constraints on community assembly in tropical rain forests. Oikos 120, 720–727.