Research Article

Short-term effects of the management intensities on structure dynamic in monoculture forests of southern subtropical China

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Abstract

Conversion from timber-dominated forestry to forest ecosystem management needs a rational management intensity to manage forest structure, which should be decided upon by managers and scientists as well as stakeholders. However, few studies have attempted to quantify optimal silvicultural measures for forest management intensity. Here, we examined the short-term effect of light and heavy management intensities on structure dynamics (tree composition, diversity, volumes and slenderness) in monoculture forests of southern subtropical China. Species diversity was generally lower in the heavy-intensity forests than in the light-intensity forests. The range in diameters was larger in the logged forest compared to control ones. The stand volume varied greatly between management intensities. Though higher trunk slenderness value (>80) indicates higher susceptibility to meteorological disturbance such as wind storm and heavy snow, trunk slenderness in the control and the heavy-intensity plots increased significantly compared to that in the light-intensity plot. These results suggest that stand structure dynamic are influenced by different management intensities. We conclude that light-intensity management enhances the richness and affects their patterns of diversity, and heavy-intensity management promotes an increase in understory diversity and regeneration but deficits in volumes and basal areas. In summary, we provide insights beyond traditional studies on different management intensities and levers to sustainable development of forestry. Our study also emphasises the importance for forest managers' understanding between management and conservation of monoculture forest. Nevertheless, variation in structure response to management intensity calls for careful consideration in future strategies, not only of which structure to favor during operations, but also, of how the treatments are applied.

Keywords: Stand structure dynamic, management intensity, management strategies, monoculture plantation

Received: 31 July 2014; Accepted 17 October 2014; Published: 23 March 2015

Cite this paper as: Jiang,J., Lu, Y., Pang, L, Liu, X., Cai, D. and Xing, H. 2015. Short-term effects of the management intensities on structure dynamic in monoculture forests of southern subtropical China. *Tropical Conservation Science* Vol.8 (1): 187-200. Available online: www.tropicalconservationscience.org

Introduction

Forests provide humanity with a wide range of essential raw materials and services, but human activities also strongly influence forest structure and habitat conditions [1], either enhancing within-stand complexity by creating treefall gaps of various sizes or reinitiating stand development by removing most or all live canopy trees [2]. As forest land is getting scarce [3], future forest production increases will, to a large extent, have to rely on rational management intensities. Yet, understanding the forest management intensity is currently limited by incomplete knowledge about the forest structure dynamic [4].

This is particularly the case in monoculture plantation forest, where the structure dynamic of logged forest and the changes that produce these patterns remain unclear [3]. It is unfortunate, because the effects of forest management on forest structure vary substantially depending on management intensity [5]. For example, the intensity by which forests are managed affects tree densities, biodiversity, tree basal area, vertical spatial distribution and ecosystem service provisioning [6]. Therefore, understanding the structure dynamic of forest management intensity and its drivers is essential to the management and conservation of subtropical monoculture forests.

Logging is the most popular management method of commercial timber production in subtropical monoculture forests, and it is also the main driver of forest degradation [7]. Its effects on forest ecosystems vary greatly, depending on intensity, frequency and recovery time [8]. Logging can affect forest structure, biodiversity, and even cause local extinction, especially in forests subjected to logging without intensive stand improvement interference [8]. However, the negative effects of logging can be minimized if improved logging intensities are properly applied [9-10]. Much knowledge about the different logging intensities and their roles in sustaining biodiversity and ecosystem functioning has been gained through studies on the changes in species diversity and composition [11]. Still, identifying and assessing forest management intensity is not easy for forest managers, particularly since people have widely different views on how to balance the use of forest resource and the conservation of monoculture forests, including the consideration of biodiversity, economic and social indicators [3].

Forestry in China is facing problems under poor forest conditions and rapid-development pressures. In recent decades, no other country in the world has established more forest plantations than China. The plantation area of south China accounts for 63 % of the total plantation area of China [12]. However, the negative effect in the management of monoculture plantations is the lack of conserving old trees and coppice stands due to short rotation cycles of 25 years [13]. Although Chinese afforestation initiatives can hardly be overrated in terms of their quantity, forests cover only approximately 18 % of China's landmass, and timber yields and quality are lower than in many other places, with China's enthusiasm for monocultures taking a heavy toll [13]. Moreover, machine-cultivated operation with monocultures of Masson pine (*Pinus massoniana*) was once the sole timber management method, which destroyed the structure of the original community, causing forest degradation and instability. Evidence of this situation in south China is the devastating damage caused by snowstorms in January 2008, when frozen rain and snow caused a loss of forest ecosystem services valued at 711.7 billion RMB [14]. These issues have prompted reconsideration of monoculture forest management to identify appropriate techniques for production, stability and conservation. Assessing forest management intensity is challenging because intensity itself is a complex term, encompassing multiple factors (e.g. tree species, biodiversity and stand structure), although logging and forest disturbances are still widespread [15]. Consequently, forest management intensity has been examined using a wide range of indicators, including tree species composition, diversity, timber volumes, silvicultural practices [16, 17]. However, few studies have attempted to quantify optimal management intensity for conservation of monoculture forests in subtropical China.

The specific objectives of this study were to determine: 1) how the tree species composition and diversity were influenced by different management intensities; 2) how different management intensities affected dynamics of structure (volume, growth and slenderness) as the forest developed; 3) the implications for policy makers seeking to balance management and conservation of monoculture forest. We hope this study will improve understanding of forest dynamic of monoculture forests, and also provide insights beyond traditional studies on management intensities and potential levers to sustainable development of forestry.

Methods

Study area

The study sites were located in the Fubo plantation station forests (21°57´–22°19´N, 106°39´–106°59´ E) of the Experimental Centre of Tropical Forestry (ECTF) of the Chinese Academy of Forestry, Pingxiang City, Guangxi Zhuang Autonomous Region, China, which belongs to the subtropical region (Fig.1). The annual rainfall in the region is 1200 to 1500 mm; the temperature is varies between 20.5°C and 21.7°C, and the relative humidity is 80 %–84 %. The area is located at an altitude of 430–680 m above sea level (a.s.l), and the topography consists of low mountains. The study site soil, with a sandy texture, was formed from granite and is classified as red soil in the Chinese soil classification, showing pH value of 4.8–5.5 [18]. The former original forest, classified as semi-deciduous lowland forest, was clear-cutting in 1992/93. Then forests in the study area were artificial, even-aged forest and afforested in 1993. The initial density of afforestation was 2500 stems per hectare, as to install Masson pine (*P. massoniana*) monoculture. Since then, there are no forest management activities for 14 years till 2007 when the thinning harvest occurred.

Experimental design

We initiated the experiment to examine the effects of the management intensity on structure dynamic during 5-years of succession in monoculture forests. In this study, harvesting systems with different thinning intensities were applied during 2007 in stands of similar site quality. We established study plots in monoculture forests of southern subtropical China (Fig.1 A and B). Three experimental treatments were employed with different management intensities at individual bases in the study forest: light intensity treatment (LT, 450 ha^{-1} remaining after logging), heavy intensity treatment (HT, 225 ha^{-1} remaining after logging), and control forests (intact stands with minimal silvicultural or human intervention) (Table 1). Stands were logged during the summer of 2007. Before the treatments, there were no statistically significant differences between the treatment categories in the total volume of dead or living trees. The harvesting equipment was restricted to the machine corridors and reached into the residual strips to remove trees, thus there was minimal disturbance of the forest floor or soils in the retained strips.

In each intensity level, a total of 20 initial permanent plots were randomly selected from the grid for field investigation. Each permanent plot consisted of an inventory circular plot of 400 m^2 (11.2 m radius) for measuring trees with diameter at breast height (DBH) ≥ 5 cm. Within each plot, a smaller 5 × 5 m subplot (25 m^2) of was placed to survey species recruitment (Fig.1 C). The DBH, height, density and coverage of tree species were recorded. DBH-measured 1.30 m above the ground, were noted and tree height was measured using an optical height meter (PM-5/1520 P, Suunto, Vantaa, Finland). For each subplot, we investigated composition and number of natural regeneration and shrub; each tree was checked to see if it was living or dead and if the dead tree was standing or had fallen. We surveyed once before the harvest in the summer of 2007, and again in the summers of 2008, 2010, and 2012.

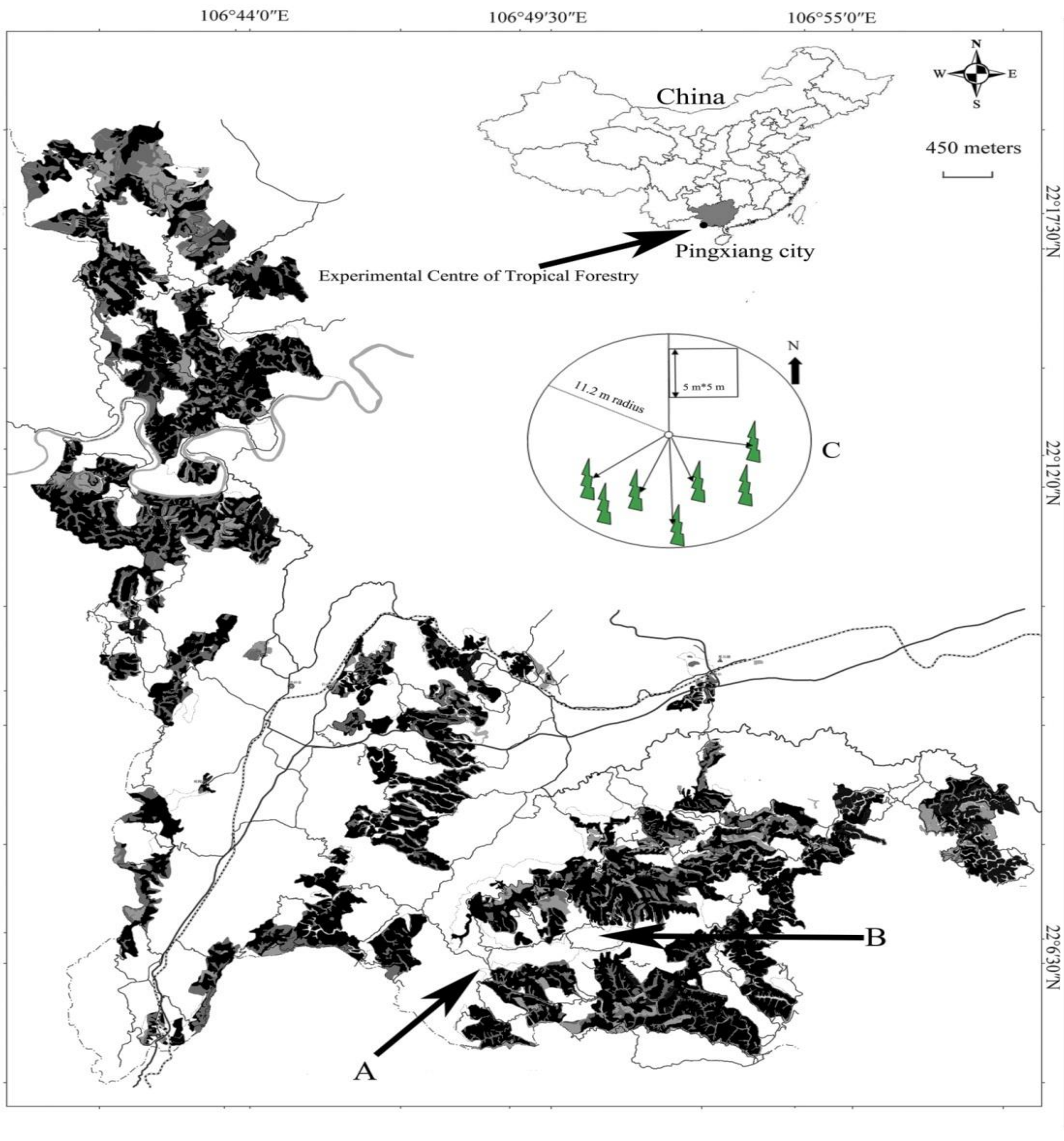

Fig.1.Study sites in the subtropical zone, near Pingxiang city, Guangxi Province, China. A and B indicates the general location of the heavy intensity and light intensity treatments plots, respectively. C represents circular plot were in each treatment.

Table 1. Quantitative information before and after thinning on the study plots (mean±SE).

Treatments	Density (stem ha^{-1})		Basal area (m^2 ha^{-1})		Stand volume (m^3 ha^{-1})	
	Before	After	Before	After	Before	After
Control	1113±101	1100±125	9.47±0.71	13.77±0.87	88.66±3.521	103.68±4.312
LT	1244±93	457±113	10.28±0.90	14.78±0.55	82.84±2.711	113.64±3.285
HT	1125±121	285±77	9.58±1.20	13.56±0.69	77.14±1.382	97.94±2.917

LT : light intensity treatment, HT :heavy intensity treatment.

Data analysis

By utilising five years (2007-2012) permanent-plot experiments conducted in monoculture forest, species richness and abundance, stand density of adult trees, DBH, height, basal area, density of tall saplings and juveniles were compared between the three treatments using a standard one-way ANOVA. Means that exhibited differences were compared using Tukey's test with a 5 % probability significance threshold to test for differences in the percent cover after the disturbances of different intensities. We quantified the diversity which was characterised based on three measures: species richness, Shannon index, Pielou's index and Simpson index were calculated separately for each plot in each study site. Species richness (S) is number of species found in a plot.

Shannon index (H') [19]: $H' = -\sum_{i=1}^{S}(P_i \ln P_i)$, where *Pi* is the stem proportion of species *i*.

Pielou's index (J) and Simpson index (D_S) was calculated as: $J = H' / \ln S$; $D_S = \sum_{i=1}^{S} \frac{N_i(N_i - 1)}{N(N-1)}$, where N_i is the number of species i , N is the total number of species.

Cumulative volume growth was calculated for every year by the basal area multiplied with the corresponding tree height and a common form factor of 0.6:

$V_t = \pi \times (\frac{DBH_t}{2})^2 \times h_t \times f$, where V_t is the volume at age t; DBH_t is the diameter at age t; h_t is the tree height at age t, and f is the form factor (the ratio of tree volume to the volume of a cylinder with the same basal diameter and height). And the periodic annual increment (PAI):

$PAI = (V_T - V_I) / a$; where V_I is the initial year (2007); V_T is the terminal year (2012); a is the years. Mean height and diameter increment were calculated by dividing height and diameter by tree age. Age was taken from records.

We hypothesize that if slenderness were critical for the stability of artificial stand, there should be an effect of thinning intensity on tree stature. Trunk slenderness was calculated as (*H/DBH)* ×100; this ratio has attained special importance in forestry because a slenderness ratio has been proposed as a failure criterion in hazard tree management [20]. The trunk slenderness of individual trees was also compared between the initial (2007) and the terminal (2012) measurements. All statistical analyses were performed with R statistical software [21]. The diversity indices were calculated with the *vegan* package.

Results

Species composition

The species richness increased similarly under the three management levels, with the highest species richness being observed in the LT plots, which increased after harvesting to 12 in 2007 and 17 in 2012 (Table 2). The number of species corresponding to the most abundant species was significantly higher for HT than under the other management levels (F=13.201; *P*=0.03). The species recorded only in LT and HT included *Triadica cochinchinensis*, *Schefflera minutistellata*, *Ficus esquiroliana*, *Toxicodendron succedaneum*, *Castanopsis hystrix* and *Erythrophleum fordii*. The density at the HT plots (DBH ≥ 5 cm) ranged from 1125 to 485 trees ha^{-1} after five years and was significantly lower in the highly disturbed forest than under the other management levels. The HT reached a maximum juvenile density of 213 trees ha^{-1}. Compared with control plot, LT and HT showed a higher density among regeneration storey. HT was also the management level at which the regeneration density was highest (233 trees ha^{-1}).

Table 2. Structural characteristics of stands under different management intensities (mean±SE).

Treatments	Year	Species	*DBH* (cm)	Height (m)	Density (Stem ha^{-1})	Regeneration stem density (Stem ha^{-1})
Control	2007	10	13.4±0.37b	13.2±0.7b	1113±101	14
	2012	12	15.7±0.29a	12.7±1.5c	982±88	21
LT	2007	12	12.3±2.1c	10.9±1.7e	1244±93	15
	2012	17	13.8±1.3b	13.8±2.2b	457±113	161
HT	2007	11	11.7±1.1d	11.3±2.1d	1125±121	13
	2012	15	15.3±0.9a	14.1±3.2a	285±77	233

Different letters indicate significant differences between management types at the *P*<0.05 level based on Tukey's test.

Diversity

In the period between 2007 and 2012, significant differences were found for most of the analysed diversity factors (Table 3). Although the diversity of tree species was rather similar in the two types of the logged forest, the Shannon index was highest in LT and lowest in control plot. The Shannon index was significantly higher in LT (2.47) than in HT (2.07) (Table 3). The highest species diversity index was also obtained in LT, with a Simpson index of 0.82 (significantly higher, $P < 0.05$). Across the HT and LT plots, the general trends were highly similar regarding Pielou's evenness, which decreased in both LT and HT from 2007 (0.54, 0.65, respectively) to 2012 (0.44, 0.59, respectively). A significant difference in Pielou's index was also detected between control and LT or control and HT, but not between LT and HT after 5 years.

Table 3. Diversity indexes of tree species under different management intensities (mean±SE).

Treatments	Shannon-Wiener index		Simpson index		Pielou's index	
	2007	2012	2007	2012	2007	2012
Control plot	0.67±0.01	1.43±0.02	0.49±0.03	0.67±0.02	0.99±0.01	0.81±0.02
LT	0.81±0.02	2.47±0.02	0.53±0.01	0.82±0.01	0.54±0.01	0.44±0.02
HT	0.78±0.01	2.07±0.70.01	0.51±0.01	0.77±0.02	0.65±0.03	0.59±0.03

Stand growth

The diameters of trees within control were generally smaller than in the logged forest (LT = 13.8±1.3 cm and HT = 15.3±0.9 cm). The total basal area in LT ranged from 10.25 to 14.78 m^2 ha^{-1}, while that in HT ranged from 9.58 to 13.56 m^2 ha^{-1} (Table 4). Compared with the control plots, the LT and HT stands showed a slightly higher tree density among small-sized trees (5 cm < DBH≤ 10 cm). In the un-logged stands, intermediate (10 cm < DBH≤ 20 cm) trees were more numerous. The difference was especially great in the larger DBH class (30 cm < DBH≤ 40 cm). The DBH distribution in HT differed significantly from that of control plot and LT among the smaller size classes due to a large number of individuals in the 30–40 cm DBH size classes. The percentage of individual trees ranged from 2.3 % in HT to 0.5 % in LT, with a high abundance of individuals in the larger size classes being observed at the managed site. HT exhibited trees with a wider range of diameters. Stand growth was reflected in both of the smaller size classes at LT (DBH 0–10 cm and 10 cm–20 cm) in 2012, which most notably accounted for 36.9 % and 41.3 % of individual trees, respectively.

Table 4. Diameter at breast height of trees in the plantation five years after harvesting (mean±SE).

Treatments	Years	*DBH* (cm)	Basal area (m^2 ha^{-1})	Percentage of tree individuals with different diameter class (%)				
				Ⅰ	Ⅱ	Ⅲ	Ⅳ	Ⅴ
Control plot	2007	13.4±0.37	9.47±0.71	19.1	62.3	18.1	0.01	-
	2012	15.7±0.29	13.77±0.87	22.8	59.7	17.5	0.02	-
LT	2007	12.3±2.1	10.28±0.90	20.7	61.2	17.3	-	-
	2012	13.8±1.3	14.78±0.55	36.9	41.3	20.3	0.5	0.09
HT	2007	11.7±1.1	9.58±1.20	18.4	62.6	18.7	-	-
	2012	15.3±0.9	13.56±0.69	20.9	34.4	20.7	2.3	0.08

Note: Ⅰ: *DBH* range 0-10 cm; Ⅱ: *DBH* range 10-20 cm; Ⅲ: *DBH* range 20-30 cm; Ⅳ: *DBH* range 30-40 cm; Ⅴ: *DBH*＞40 cm.

Stand volume

Stand volumes were significantly greater in LT than in control plot and HT (Table 5). Stand volume exhibited significant differences among different management types. LT exhibited the greatest stand volume (113.64 m^3 ha^{-1}), with the total living stand volume increasing from 113.64 to 82.84

m^3 ha^{-1} over the 5-year period in HT. HT presented the lowest volume (97.94 m^3 ha^{-1}), and control plot showed an intermediate value (103.68 m^3 ha^{-1}). However, the individual volume did not differ between control plot and the logged forest (LT and HT). The overall current stand volume conditions found within the logged forest and the control plot differed significantly based on the different management intensities.

Table 5. Volume growth under different management intensities (mean±SE).

Treatments	Individual volume (m^3)			Stand volume (m^3 ha^{-1})		
	2007	2012	*PAI* ($m^3 \cdot ha^{-1} \cdot year^{-1}$)	2007	2012	*PAI* ($m^3 \cdot ha^{-1} \cdot year^{-1}$)
Control plot	0.078±0.006a	0.127±0.01a	0.0098±0.0003	88.66±3.521	103.68±4.312a	3.00±0.04
LT	0.081±0.005a	0.167±0.006b	0.0172±0.0001	82.84±2.711a	113.64±3.285b	6.16±0.04
HT	0.082±0.004a	0.148±0.003a	0.0132±0.0001	77.14±1.382b	97.94±2.917c	4.16±0.02

Different letters for data in the same row or column indicate significant difference among treatments.
PAI: periodic annual increment (2007-2012).

Changes in trunk slenderness

Trunk slenderness in control plot, LT and HT with respect to the DBH is shown in table 6. Trunk slenderness exhibited a general trend towards the DBH and the slenderness of trees under different management intensities over the five study years (Fig.2). The distribution of slenderness in LT (R^2=0.58) differed greatly from that in control plot (R^2= 0.41) and HT (R^2=0.83). Focusing on trees presenting a trunk slenderness value of 80, or a ratio < 80, the slenderness value in the LT plot tended to be greater than under the HT and control plot, with the peak of the distribution appearing in the 10 cm–20 cm DBH class in HT and the 20 cm–30 cm DBH class in HT. Compared with 1.3 % in HT, no trees exceeding the threshold were newly observed in the > 40 cm DBH class in HT and control plot.

Table 6. Frequency of individuals (%) with<80 in slenderness in different management intensities.

Treatments	Year	Frequency of individuals (%)				
		Ⅰ	Ⅱ	Ⅲ	Ⅳ	Ⅴ
Control plot	2012	7.5	19.1	20.3	0.02	-
LT	2012	21.2	29.7	28.5	0.5	-
HT	2012	10.2	17.2	18.2	5.6	1.3

Note: Ⅰ: *DBH r*ange 0-10 cm; Ⅱ: *DBH* range 10-20 cm; Ⅲ: *DBH* range 20-30 cm; Ⅳ: *DBH* range 30-40 cm; Ⅴ: *DBH*＞40 cm.

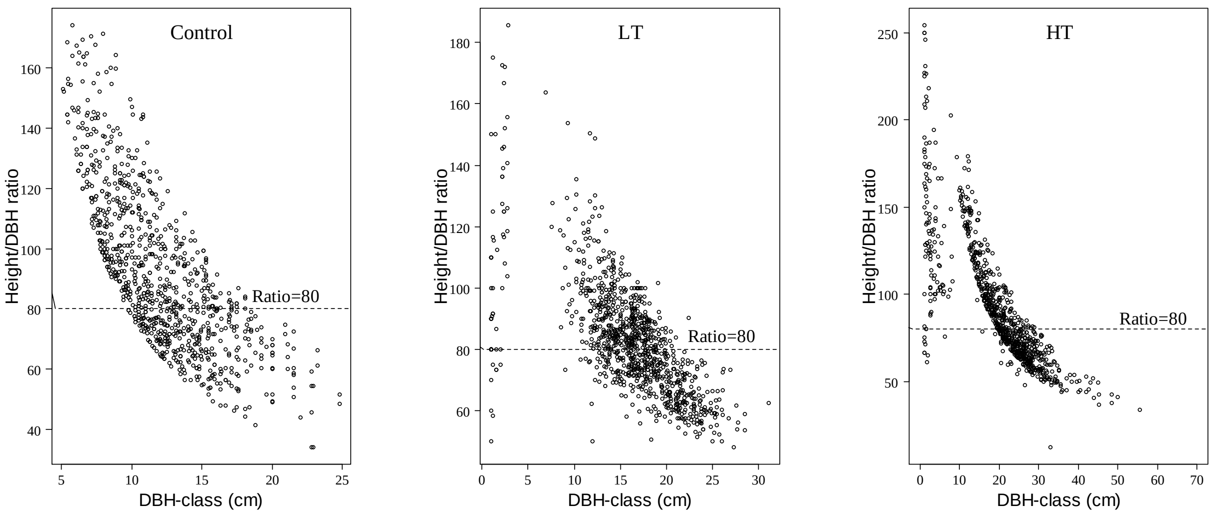

Fig. 2. Change in trunk slenderness associated with different DBH-class under three different management regimes.

Discussion

Structural dynamics following different management intensities

Our study aimed to test whether disturbances intensities affect the tree structural dynamics through a controlled experiment. In general, species diversity was increased under either light-intensity, or heavy-intensity compared with control stand [22]. Our results demonstrated that the species richness and diversity differed significantly between two different management intensities, remaining distinct from the monoculture in terms of species diversity, especially in the light-intensity treatment. The species richness depends on the differential responses of regeneration species to the disturbance intensity: some species may tolerate such disturbances, while others may become locally extinct. This trend is consistent with the previous observations of Bergstedt et al. [23] following the application of different logging intensities and Götmark et al. [24] regarding selection cutting and suggests important changes in the ability of species to reproduce vegetatively, enabling them to rapidly increase their coverage of stand development if they survive in the plots. The tree densities measured in the light-intensity and heavy-intensity stands were similar, but were lower than in control plot, suggesting that the application of harvest over time alters characteristic of monocultures stands.

The diversity index was higher in the logged forest compared the un-logged forest. A gain in diversity after selection or partial logging has also been reported by Thomas et al. for Douglas-fir stands [25]. The increases in the logged forests (light-and heavy-intensity) are likely to be a consequence of high environmental heterogeneity [26] regarding light availability after logging, favouring especially light-demanding and wind-dispersed herbs and annual species. For example, the coverage of *Ficus esquiroliana*, *Toxicodendron succedaneum* and *Melicope pteleifolia* was particularly increased after treatments; these species are capable of rapid dispersal to new sites from adjacent open areas [27]. When a forest has long remained undisturbed and is dominated by slow growing late successional species, large and medium-sized gaps created by logging and post-logging treatments might increase diversity [28]. Furthermore, species that are sensitive to disturbance were still persistent after logging, despite decreasing in abundance, indicating the potential for a rapid recovery once pioneer tree species expand. Consequently, these species are very competitive and account for the increasing relative abundance of competitive species over time in the logged forest.

Variation of diameter distribution and growth among management intensities

The presence of trees in smaller-sized DBH classes indicates partial recruitment in the logged forest as well. The basal area was also higher in the logged forest compared with control plots. However, light-intensity and heavy-intensity presented statistically similar basal areas. These trends reflected both the lower abundance of trees in the logged forest and the small diameter of trees that remained, due to the preferential removal of larger-diameter individuals. A pattern of decreasing overall stem densities with increasing diameter size classes is a typical characteristic of secondary tropical forests [17, 29]. In all of the logged forest we studied, a large number of individuals were found in the 5 to 10 cm diameter size class. This pattern was observed due to the presence of small-sized trees, which indicates that the stand structure was more complex in the logged forest [30].
The volume was significantly greater in the logged forest compared with un-logged forest: the individual volumes within heavy-intensity were slightly smaller than in light-intensity. Stand volume showed a similar trend. Thus, an increase in the management intensity could lead to a reduced volume during the further development of the forest. Heavy-intensity management creates gaps of varying size, mimicking natural gap dynamics within stands. Thus, heavy-intensity favours an increase in understory diversity and tree regeneration but deficits in volumes and basal areas compared with light-intensity. These results clearly indicated that the management intensity influences the harvest volume and regeneration, which has implications regarding the potential effects of different management intensities are reflected among individual trees in response to forest management.

Compared with control plot, light-intensity management was more effective in generating a live-tree diameter composition and stand volume that approximated those found in our study, suggesting that light-intensity management may achieve these conditions more rapidly than heavy-intensity. The main reason is that a low degree of thinning creates gaps to improve the increases in light and soil temperature [31], promoting the rapid growth and accumulation of material retained in trees, in agreement with the findings of Pukkala [32]. Second, we assume that if heavy-intensity management is continued, it will likely have an adverse effect on regeneration of the study species due to declining seed resources as well as competition from some fast growing shrubs. Third, light-intensity management may favour species with dormant below-ground buds, on either roots or below-ground stems, especially herbs and heliophyte species, along with soil properties [33]. Therefore, the appropriate management intensity should be considered to achieve sustainable management.

Changes in trunk slenderness among the different management intensities

Trunk slenderness has been used as an indicator of stand stability in forestry for many years; it is also correlated with susceptibility to wind and snow damage [20, 34-35]. As reported in mature coastal forest [36], according to the slenderness ratio, all trees beyond the threshold are potential hazard trees [37] and would require pruning or logging treatments. Mattheck [20] proposed a slenderness ratio of 50 as a failure criterion in hazard tree management, which represents the trade-off between the relative height growth rate and the relative diameter growth rate at individual base, will be suitable to evaluate the allocation. Our study focused on trees showing slenderness values < 80, which corresponded to the height–diameter relationship of the dominant trees (mean DBH and mean tree height) in the logged forest. These trees invested more resources in radial growth than increasing their height, which suggests that trees in the logged forest have space to expand their crowns horizontally, thus grow radially [36]. In contrast, a great many spindly trees showing trunk slenderness values > 80 were observed in control plot. The trees in the control plot were more slender than in the logged forest because of more small slender trees. For taller trees, the probability of being slender will increase susceptibility to meteorological damage. Because radial growth was suppress, taller trees developed a short, narrow crown and were stressed by other trees, once the density of the main canopy became too high. In addition, these trees showed a sharp drop in the mechanical stability, which will make them vulnerable to natural disasters in the upper forest, such as the impacts of frozen rain and wind [35].

Implications for conservation

Our results have several practical implications for forest managers and stakeholders seeking to balance management and conservation of monoculture forest.

First, our study revealed variation in structure response to management intensity calls for careful consideration prior to implementation, not only of how the intensities are applied, but also which species to favor during operations. For example, the high sensitivity of stand structure to management intensity suggests the need for a higher intensity to sustain the growth of this species. However, high-intensity harvesting could only give fast-growing species (i.e.*Eucalyptus robusta*). In this respect, light intensity harvesting may promote growth of high-value trees such as the *Dalbergia odorifera* and *Erythrophleum fordii*. The positive association observed in the light intensity management stands suggests that such species facilitation effects may persist, shaping the longer-term development of monoculture forests.

Second, the traditional harvesting method (e.g. clear-cutting) of *P. massoniana* monoculture is not sustainable and might have negative future impacts for the species population as well as for the local inhabitants. Our analysis indicated potential for increasing timber yields through light-intensity harvesting in the monoculture forests. Moreover, future strategies could focus on the establishment of management intensities and cutting limits based on slenderness and ecological criteria, to reduce the exploitation pressure on the populations of *P. massoniana* would be the performance of reforestation of degraded areas in the this region. For example, the established strategies defines diameter cutting limits (DCLs), protecting target tree and felling cycles for regular management plans with low slenderness value (< 80) , or, alternatively, management plans with low intensities applying a shorter felling cycle. In that way, such analyses can help identifying sustainable solutions by supporting management decisions.

Third, although forest managers are trained to set targets to optimize timber production, they should play a significant role for guiding ecologically sustainable practices and contribute positively for biodiversity conservation and for the maintenance of ecological processes and services. Although the Chinese government has widely recognized that monoculture forests should be managed in an ecologically sustainable way, market pressure has lead the forest industry to management regimes far from ideal from a conservation view-point. As we pursued our thinking on strategies and conservation targets, the trade-offs between forestry and conservation should be clarified, and thus ultimately to implement more sustainable forestry systems.

In this paper, we highlight the potential of such analyses to provide insights beyond traditional studies on different management intensities. Similar to agricultural systems, the question whether to integrate forest management and conservation in the monoculture becomes an important question for forest managers. Clearly, there is no perfect answer to this question, but structure dynamic analyses such as ours are an important prerequisite to better understanding which strategies could be implemented and what the potential benefits and trade-offs of both strategies are. Anyway, if conservation planning could catch up with forest economy, we would stand a better chance of maintaining not only productive forests, but also the rich biodiversity that is essential to ensure long-term forest ecosystem function.

Acknowledgments

This study was jointly funded by Sino-German joint project of Study on Innovative Technologies of Multi-Functional Forest Management (CAFYBB2012013&Lin^{2}Value). We gratefully acknowledge the support from the Chinese Academy of Forestry's Experimental Center of Tropical Forestry. We would like to thank Dr. April Yang for help in language editing. We thank anonymous reviewers and editors for their helpful comments that contributed to improve the manuscript.

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