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Original article

Comparing floristic composition in treefall gaps of certified, conventionally managed and natural forests of northern Honduras

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Keywords:
floristic composition /
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Abstract
• Forest certification sets requirements for minimizing the impacts of logging on the natural structure and floristic composition of forests.
• We assessed the impact of certification by comparing the floristic composition of 52 taxa of trees and shrubs in the treefall gaps of certified, conventionally managed and protected forests in northern Honduras.
• The highest abundance of light-benefiting taxa was found in certified forests, whereas conventionally managed forests were floristically more similar to natural forests. The environmental conditions measured in certified gaps were not favourable for a natural forest floristic composition.
• Past logging may have altered the species composition in certified forests relatively more than in conventionally managed forests. This implies that the need for restoration operations should be considered in certification requirements, along with landscape-level planning to enhance post-logging recovery.

Mots-clés :
composition floristique /
certification forestière /
trouée d'exploitation forestière /
Honduras /
exploitation forestière à impact réduit

Résumé – Comparaison de la composition floristique dans les trouées d'abattage d'arbres dans les forêts certifiées, conventionnellement gérées et naturelles du Nord du Honduras.
• La certification forestière définit des exigences pour minimiser les impacts de l'exploitation forestière sur la structure naturelle et la composition floristique des forêts.
• Nous avons évalué l'impact de la certification, en comparant la composition floristique de 52 taxons d'arbres et d'arbustes dans les trouées d'abattage d'arbres de forêts certifiées, conventionnellement gérées et protégées du Nord du Honduras.
• La plus grande abondance des taxons profitant de la lumière a été trouvée dans les forêts certifiées, alors que les forêts gérées de façon conventionnelle ont été floristiquement plus proches des forêts naturelles. Les conditions environnementales mesurées dans les trouées certifiées n'étaient pas favorables à une composition floristique de forêt naturelle.
• L'exploitation forestière passée, peut avoir modifié la composition des espèces dans les forêts certifiées relativement plus que dans les forêts gérées. Cela implique que le besoin d'opérations de restauration doit être pris en compte dans les exigences de certification.

Abbreviations: FSC – Forest Stewardship Council; CeF – Certified forest; CoM – Conventionally managed forest; NaF – Natural (protected) forest; RIL – Reduced-impact logging; MN – Management-neutral; MS – Management-sensitive.

1. INTRODUCTION

In recent years, environmental certification has been promoted as a way to achieve sustainable forest management. Nevertheless, only a few percent of tropical forests have been certified (UNECE/FAO, 2008), and few studies have examined the ecological impacts of certification on tropical systems. The main certifier of tropical forests is the Forest Stewardship Council (FSC) (van Kooten et al., 2005). The FSC requires that certified management fulfils certain ecological, social and economic criteria (FSC, 2004). In selectively logged tropical forests, the aims of ecologically sustainable forest management include maintenance of the natural forest (NaF) structure, biodiversity and ecological processes. In practice, the requirements for certified management mainly consist of implementing pre-harvest planning and reduced-impact

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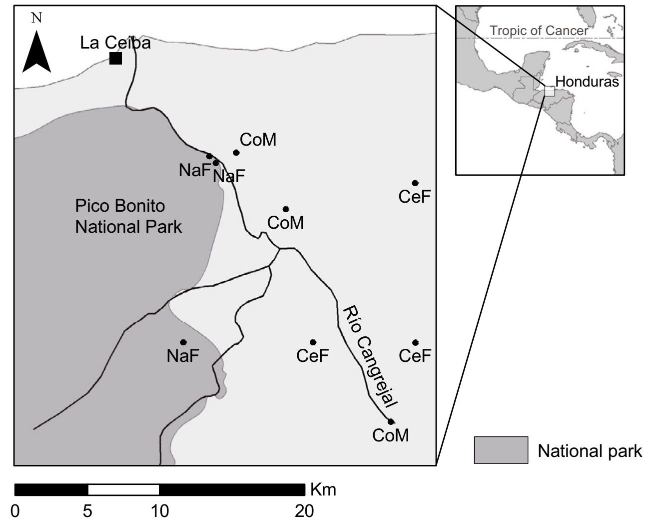

Figure 1. Location of sampled certified (CeF), natural (NaF) and conventionally managed (CoM) forests in relation to the city of La Ceiba (15° 38′ N, 86° 40′ W).

logging (RIL) techniques, along with the protection of vulnerable species and ecosystems.

Studies comparing RIL with conventional logging practices show that the use of RIL practices may effectively limit the negative impacts of selective logging on forest structure and composition (Sist et al., 2003). Controlling harvesting intensity helps to prevent a decrease in the abundance of valuable timber species (Sist et al., 1998), and limiting mechanical logging damage prevents damage to trees in residual stands (Chapman and Chapman, 1997). At the forest level, these activities reduce ground-level disturbance (Uhl and Vieira, 1989) and the opening of the canopy cover (Pereira et al., 2002), helping to control the increase in the relative abundance of light-benefiting pioneer species (Primack and Lee, 1991).

We examined the ecological impact of certified forest (CeF) management by comparing CeFs with protected NaFs and conventionally managed forests (CoMs). Two expectations were defined to evaluate the impact of CeF management at the level of a single treefall gap. First, due to improvements related to limiting harvest intensity and mechanical logging damage in CeFs, we expected the floristic composition to be more similar between CeF and NaF gaps than between CoM and NaF gaps. Second, we expected that certified management practices would better mimic the natural disturbance regime, thus creating gap conditions that support a floristic composition similar to that of a natural forest.

2. MATERIAL AND METHODS

2.1. Study sites

The studied forests are situated in the Río Cangrejal watershed in northern Honduras (Fig. 1). They are classified as tropical moist and premontane wet forests (Holdridge, 1967). Typical tree species include *Euterpe precatoria* Mart. (Arecaceae), *Vochysia* spp. Aubl (Vochysiaceae) (Salazar, 2000), *Genipa americana* L. (Rubiaceae) and *Terminalia amazonia* (J.F. Gmel.) Exell (Combretaceae) (Ferrando, 1998). A description of the climatic conditions of the area can be found in Kukkonen et al. (2008).

Uncontrolled selective loggings in Río Cangrejal began on a major scale in the 1970s. Early loggings focused on a few valuable species, including *Swietenia macrophylla* King (Meliaceae) and *Cedrela odorata* L. (Meliaceae) (Markopoulos, 1999). After these species became rare, the range of marketed timbers expanded, and currently covers about 20 species.

The CeFs and CoMs studied are owned by the state and managed by local community forest groups under a usufruct agreement. Each forest group harvests a segment of 10 to 20 ha of forest each year, with annual logging intensities between 2.2 and 6.5 trees per ha. The rotation period is 30 years. The NaFs studied were located in Pico Bonito National Park, which borders the managed forests in the Río Cangrejal watershed. Our sample sites were situated in areas of restricted human intervention.

2.2. Sampling

We selected three replicate forests within each management type (CeF, CoM and NaF) (Tab. I). Five logging gaps were sampled in each CeF and CoM and five natural treefall gaps in each NaF (apart from Pico Bonito, where six treefall gaps were sampled). Within each of the 46 treefall gaps, we sampled three round 100-m^2 plots, situated in the stump, bole and canopy sites where the tree had fallen. The stump site was situated to exclude the tree stump itself and possible sprouts. The bole site was situated in the centre of the trunk of the fallen tree, and the canopy site was situated in the middle of the crown. At each site, we recorded all woody plants ≥ 1 cm in dbh (diameter-at-breast height). Samples were identified to species, or when this was impossible, to the genus level. Two species (*Persea schiedeana* Nees and *Conostegia xalapensis* (Bonpl.) D. Don ex DC.) with fewer than 10 recorded individuals were removed from the dataset. The final dataset thus consisted of 52 tree and shrub taxa (Tab. II).

We also recorded a total of 15 environmental variables in the sampled gaps. For the analyses, these were divided into two subgroups (cf. Kukkonen et al., 2008): management-neutral (MN) and management-sensitive (MS) gap characteristics (Tab. A, available online at www.afs-journal.org). The MN gap characteristics were expected to be neutral with regard to management type, whereas the variables included in the MS subgroup were expected to be sensitive to differences in management type. Stem density was included in the MS gap characteristics, because reduced damage in CeF management may increase the density of surviving advance regeneration (Jackson et al., 2002). The abundance of lianas (Schnitzer and Bongers, 2002), herbs (Cusack and Montagnini, 2004) and shrubs (Denslow et al., 1990) has been shown to decrease with reduced mechanical logging damage. The abundance of trees and the coverage of litter may be positively affected by reduced disturbance (Dickinson et al., 2000).

2.3. Data analyses

We used constrained ordination to study the variation in floristic data between management types (CeF, CoM and NaF). A preliminary

Table I. Description of the studied forests.

Forest	Geographic coordinates (in decimal degrees)	Size of production forest (ha)	Altitude (m, a.s.l.)	Total sapling density in gaps (mean ± SD)	Gap age (y, mean ± SD)	Gap size (m^2, mean ± SD)
CeF 1 (Río Viejo)	15.60 111,86.66 722	618	930	240 ± 51	8.0 ± 0.0	199 ± 43
CeF 2 (Toncontín)	15.60 083,86.60 111	1061	900	183 ± 57	2.8 ± 0.8	235 ± 131
CeF 3 (Yaruca)	15.70 028,86.60 111	625	650	171 ± 43	5.6 ± 0.5	170 ± 33
CeF (total mean)	–	768	827	198 ± 56	5.5 ± 2.3	201 ± 80
CoM 1 (El Naranjo)	15.71 806,86.71 722	1682	250	186 ± 81	2.6 ± 0.5	259 ± 76
CoM 2 (El Pital)	15.68 417,86.68 472	N/A	500	206 ± 29	2.4 ± 0.5	293 ± 112
CoM 3 (El Urraco)	15.55 139,86.61 722	1709	950	69 ± 43	6.4 ± 2.2	252 ± 61
CoM (total mean)	–	1331	567	154 ± 81	3.8 ± 2.3	268 ± 82
NaF 1 (Las Mangas)	15.71 694,86.71 806	–	850	178 ± 69	6.8 ± 1.1	269 ± 191
NaF 2 (La Primavera)	15.60 111,86.75 083	–	200	158 ± 6	7.2 ± 0.4	381 ± 130
NaF 3 (Pico Bonito)	15.71 722,86.73 389	–	200	163 ± 19	5.8 ± 1.3	251 ± 160
NaF (total mean)	–	–	403	166 ± 38	6.6 ± 1.2	297 ± 162

detrended canonical correspondence analysis (DCCA) was run to select between linear and unimodal ordination methods (after ter Braak and Šmilauer, 2002). We selected linear ordination based on the relatively low extent of species turnover along the DCCA axes (gradient length < 3). The linear form of constrained ordination is redundancy analysis (RDA), in which the distances between sample scores correspond to Euclidean distances in ordination space. Preliminary RDA showed that when all measured environmental variables were used as explanatory variables, the first two ordination axes explained 48.6% of the variation in floristic data.

To extract the variation explained by the MN and MS gap characteristics from the floristic data matrix before studying the residual variation with respect to the variables of interest, we used partial redundancy analysis (pRDA). Two pRDAs were conducted to test the expectations. With the first pRDA, we tested whether the floristic similarity between the CeF and NaF gaps was higher than that between the CoM and NaF gaps. To eliminate initial differences in the MN gap characteristics (gap age, altitude, inclination, gap size, distance and percentage coverage of stones and deadwood), these were set as covariables (after Lepš and Šmilauer, 2003). The second pRDA was performed to assess the role of MS gap characteristics in explaining the differences in floristic similarity between the CeF and NaF gaps and the CoM and NaF gaps. This was performed by adding the MS gap characteristics (density and coverage of lianas, herbs, shrubs, litter, young and canopy trees) to the covariables together with the MN gap characteristics.

The pRDAs only accounted for that part of the variation that could be explained by the management type. To test the effect of management type in an unconstrained ordination space, i.e. to include all variation in floristic data, we conducted two principal component analysis (PCA) ordinations using the same sets of covariables. Differences in floristic composition among management types were tested by conducting analyses of variance (ANOVA) for the sample scores based on species composition on the first two axes in all ordinations. If significance was observed, the ANOVAs were followed by Dunnett's tests for pairwise comparisons between classes.

To conduct the pRDAs and PCAs we used the ecological ordination program CANOCO 4.5 (Plant Research International, Wageningen, the Netherlands) (ter Braak and Šmilauer, 2006). We selected centring by species and scaling focused on inter-sample distances. For the species data, a square-root transformation was conducted. All environmental variables were centred and standardized to zero mean and a variance of 1 (Lepš and Šmilauer, 2003). ANOVA and Dunnett's tests were carried out using the statistical package SPSS (SPSS Inc., 2007).

3. RESULTS

3.1. Floristic similarities

According to the results, the floristic similarity between the CeF and NaF gaps was lower than that between the CoM and NaF gaps. The first pRDA (Fig. 2) showed that the Euclidean distance between the CeF and NaF gaps (0.40) was 1.5 times higher than that between the CoM and NaF gaps (0.26). The MN variables explained 34.9% of the variation in floristic composition. With the MN variables set as covariables, this effect was factored out prior to the analysis. Management type explained 12.3% of the remaining variation, with the first constrained axis explaining 10.2% and the second 2.2% of the variation. The third and fourth unconstrained axes explained 10.2% and 7.8%, respectively, indicating that there were significant environmental gradients not included in the analysis.

The effect of management type was statistically significant along the first, as well as the second axis sample scores (Tab. III). The Dunnett's tests revealed that the differences between the CeF and NaF gaps were statistically significant, whereas those between the CoM and NaF gaps were not (Tab. III). The PCA results confirmed that management type was a significant predictor of floristic composition. When the MN gap characteristics were set as covariables, the effect of management type was significant along the first axis (Tab. III). As in the pRDA, the Dunnett's tests showed that the differences between the CeF and NaF gaps were statistically significant, whereas those between the CoM and NaF gaps were not. Along the second axis, however, no similar trend was observed.

3.2. Gap environmental conditions

The results revealed that the gap conditions in the CeFs were not as favourable for a near-natural floristic composition as the gap conditions in the CoMs. When the effect of the

Table II. List of taxa with family names and abbreviations used.

Species/genus name	Family	Abbreviation
Alchornea latifolia Sw.	Euphorbiaceae	ALCLAT
Billia hippocastanum Peyr.	Hippocastanaceae	BILHIP
Brosimum alicastrum Sw.	Moraceae	BROALI
Callicarpa acuminata Kunth	Verbenaceae	CALACU
Calophyllum brasiliense Cambess.	Clusiaceae	CALBRA
Calyptranthes chytraculia (L.) Sw.	Myrtaceae	CALCHY
Carpotroche platyptera Pittier	Flacourtiaceae	CARPLA
Cecropia peltata L.	Cecropiaceae	CECPEL
Cephaelis tomentosa (Aubl.) Vahl (= *Psychotria poeppigiana* Müll. Arg.)	Rubiaceae	CEPTOM
Cephaelis Sw. sp. (= *Psychotria* L. sp.)	Rubiaceae	CEPH_SP
Cestrum racemosum Ruiz & Pav.	Solanaceae	CESRAC
Cojoba arborea (L.) Britton & Rose	Fabaceae	COJARB
Cordia alliodora (Ruiz & Pav.) Oken	Boraginaceae	CORALL
Cupania guatemalensis (Turcz.) Radlk.	Sapindaceae	CUPGUA
Dendropanax arboreus (L.) Decne. & Planch.	Araliaceae	DENARB
Dialium guianense (Aubl.) Sandwith (= *Arouna guianensis* Aubl.)	Fabaceae	DIAGUI
Dichapetalum bullatum Standl. & Steyerm.	Dichapetalaceae	DICBUL
Eugenia L. sp.	Myrtaceae	EUGE_SP
Garcinia intermedia (Pittier) Hammel	Clusiaceae	GARINT
Guarea grandifolia DC.	Meliaceae	GUAGRA
Guarea macrophylla Vahl	Meliaceae	GUAMAC
Hamelia patens Jacq.	Rubiaceae	HAMPAT
Heliocarpus appendiculatus Turcz.	Tiliaceae	HELAPP
Huertea cubensis Griseb.	Staphyleaceae	HUECUB
Hyeronima alchorneoides Allemão	Euphorbiaceae	HYEALC
Inga Mill. spp.	Fabaceae	INGA_SP
Licania platypus (Hemsl.) Fritsch	Chrysobalanaceae	LICAN_SP
Licaria capitata (Schltdl. & Cham.) Kosterm.	Lauraceae	LICCAP
Licaria Aubl. spp.	Lauraceae	LICAR_SP
Lonchocarpus guatemalensis Benth.	Fabaceae	LONGUA
Matayba oppositifolia (A. Rich.) Britton	Sapindaceae	MATOPP
Miconia Ruiz & Pav. sp.	Melastomataceae	MICO_SP
Mortoniodendron vestitum Lundell	Tiliaceae	MORVES
Ochroma pyramidale (Cav. ex Lam.) Urb.	Bombacaceae	OCHPYR
Pachira aquatica Aubl.	Bombacaceae	PACAQU
Pausandra trianae (Müll. Arg.) Baill.	Euphorbiaceae	PAUTRI
Pentagonia macrophylla Benth.	Rubiaceae	PENMAC
Perymenium grande Hemsl.	Asteraceae	PERGRA
Piper auritum Kunth	Piperaceae	PIPAUR
Piper L. spp.	Piperaceae	PIPE_SP
Piper umbellatum L.	Piperaceae	PIPUMB
Pterocarpus rohrii Vahl	Fabaceae	PTEROH
Rinorea hummelii Sprague	Violaceae	RINHUM
Schizolobium parahyba (Vell.) S.F. Blake	Fabaceae	SCHPAR
Simarouba glauca DC.	Simaroubaceae	SIMGLA
Terminalia amazonia (J.F. Gmel.) Exell	Combretaceae	TERAMA
Trema micrantha (L.) Blume	Ulmaceae	TREMIC
Trichospermum sp. Blume	Tiliaceae	TRIC_SP
Virola koschnyi Warb.	Myristicaceae	VIRKOS
Vismia guianensis (Aubl.) Pers.	Clusiaceae	VISGUI
Vismia baccifera (L.) Triana & Planch.	Clusiaceae	VISBAC
Xylopia frutescens Aubl.	Annonaceae	XYLFRU
Total		52

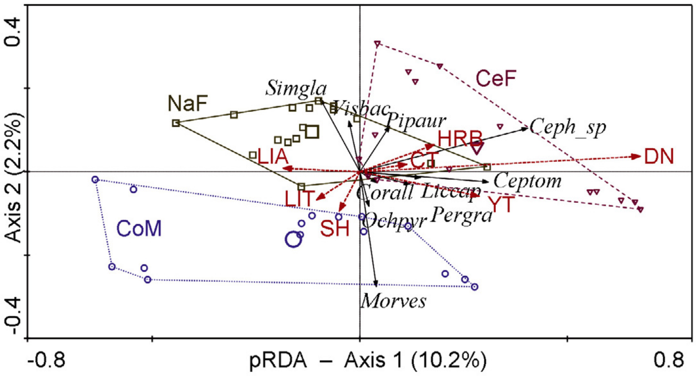

Figure 2. Partial redundancy analysis (pRDA) ordination diagram, plotting sample (gap) scores (small symbols) and class centroids of forest management types (large symbols) along with 10 taxa having the best fit. Distances between sample scores and between centroids correspond to Euclidean distances. Envelopes are drawn around samples of each management type, with sample scores represented as symbols (CeF = down triangle, CoM = circle, NaF = square). Arrows representing taxa point in the direction of increasing abundance. Axes 1 and 2 are constrained: management type is used as the explanatory variable. The percentage of variance in the floristic dataset (52 taxa) explained by each axis is indicated in brackets. Management-neutral (MN) gap characteristics are used as covariables. Management-sensitive (MS) gap characteristics are supplementary variables added to the ordination post hoc by regressing their data onto the ordination axes. Abbreviations for MS gap characteristics are as follows: DN = density, HRB = herb coverage, SH = shrub coverage, LIT = litter coverage, LIA = liana coverage, CT = coverage of canopy trees, YT = coverage of young trees.

Table III. Results of testing the significance of forest management type on the sample scores that are based on floristic composition. Sample scores are derived from constrained linear ordination (pRDA) and unconstrained linear ordination (PCA). *P*–values below 0.05 are given in bold.

Analysis	Covariables	Axis	ANOVA		Dunnett's test P	
			F	P	CeF-NaF	CoM-NaF
First pRDA	Management-neutral (MN)	Axis 1	7.863	< **0.001**	**0.004**	0.907
		Axis 2	12.636	< **0.001**	< **0.001**	0.749
Second pRDA	MN with management-sensitive (MS)	Axis 1	2.642	0.083	–	–
		Axis 2	7.712	< **0.001**	0.975	**0.002**
First PCA	Management-neutral (MN)	Axis 1	6.171	**0.004**	**0.004**	0.811
		Axis 2	0.292	0.748	–	–
Second PCA	MN with management-sensitive (MS)	Axis 1	0.719	0.493	–	–
		Axis 2	0.935	0.401	–	–

MS gap characteristics was factored out along with the MN gap characteristics in the second pRDA (Fig. 3), management type explained only 6.0% of the remaining variation in floristic composition. Thus, nearly half of the variation explained by management type was accounted for by the MS gap characteristics. Unlike in the first pRDA, the CeF and NaF gaps were more similar floristically (Euclidean distance 0.20) than the CoM and NaF gaps (0.21). Thus, the difference in floristic similarity between the CeF and NaF gaps and the CoM and NaF gaps was explained by the effect of MS gap characteristics.

The two constrained axes of the second pRDA explained only 4.3% and 1.8% of the variation in floristic data, whereas the third and fourth unconstrained axes explained 7.7% and 5.8%, demonstrating that important environmental gradients remained outside the analysis, despite controlling for the effect of MS gap characteristics. Along the first axis, the sample scores were not related to management type, whereas along the second axis they were (Tab. III). Dunnett's tests revealed that on the second axis, the difference between the CoM and NaF gaps was statistically significant, whereas that between the CeF and NaF gaps was not (Tab. III). According to the results of PCA, when the MS gap characteristics were added to the set of covariables, the differences between management types were not significant on either axis (Tab. III), confirming that MS variables explained the variation along management type.

3.3. Distribution of taxa

Altogether, we recorded 4176 individuals of the 52 taxa in the 46 gaps studied. The highest number of taxa was found in the NaF gaps (mean with SD 18.8 ± 5.8), followed by those in the CoM (15.5 ± 6.4) and the CeF (14.1 ± 5.3). The differences in taxa richness were almost statistically significant (ANOVA; $F = 3.082$, $P = 0.056$). The highest density of recorded taxa was found in the CeF gaps (111.3 ± 55.1 individuals per gap),

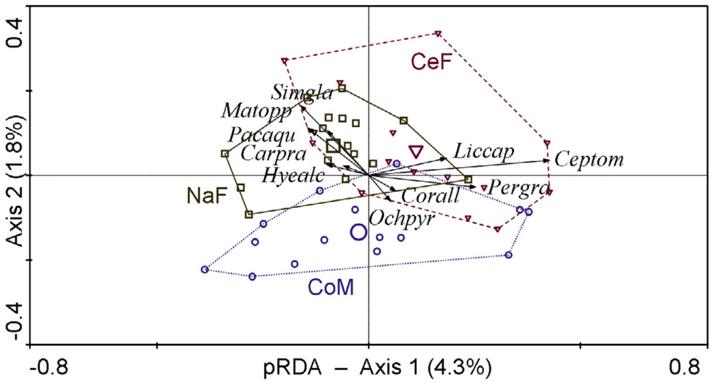

Figure 3. Partial redundancy analysis (pRDA) ordination diagram, plotting sample (gap) scores (small symbols) and class centroids of forest management types (large symbols) along with 10 taxa having the best fit. Distances between sample scores and between centroids correspond to Euclidean distances. Envelopes are drawn around samples of each management type, with sample scores represented as symbols (CeF = down triangle, CoM = circle, NaF = square). Axes 1 and 2 are constrained: management type is used as the explanatory variable. The percentage of variance in the floristic dataset (52 taxa) explained by each axis is indicated in brackets. Management-neutral (MN) gap characteristics as well as management-sensitive (MS) gap characteristics are used as covariables.

followed by the NaF (84.4 ± 28.2) and CoM gaps (77.1±57.2). The differences in density were not significant (ANOVA; F = 2.091, P = 0.136).

Figure 2 presents the 10 taxa with the best fit, i.e. highest percentage of variability in abundance explained by management type. *Cephaelis* Sw. sp. (=*Psychotria* L. sp) was most strongly associated with the CeF gaps; 26.9% of the variation in *Cephaelis* abundance was explained by the two constrained axes. In order of increasing length of the projecting species arrow to the CeF centroid, the species associated with CeF gaps included *Cephaelis tomentosa* (Aubl.) Vahl (=*Psychotria poeppigiana* Müll. Arg.) (38.8% of the variation explained), *Licaria capitata* (Schltdl. & Cham.) Kosterm. (19.3%), *Perymenium grande* Hemsl. (19.5%) and *Cordia alliodora* (Ruiz & Pav.) Oken (15.8%). The CeF gaps were characterized by the highest stem density, highest coverage of young and canopy trees, and lowest coverage of litter, lianas and shrubs (Fig. 2). Density was strongly correlated (r = 0.69) with Axis 1, which separated CeF from the other management types.

Mortoniodendron vestitum Lundell (12.3%) was most strongly associated with the CoM gaps, followed by *Ochroma pyramidale* (Cav. ex Lam.) Urb. (14.2%) (Fig. 3). The CoM sites were separated from the other management types along Axis 2, which correlated negatively with the coverage of shrubs (r = −0.21) and litter (r = −0.16) (Fig. 3).

The NaF gaps were generally characterized by a higher number of associated species compared to CeF or CoM gaps. The species with the strongest association with the NaF gaps was *Simarouba glauca* DC. (17.1%), followed by *Vismia baccifera* (L.) Triana and Planch. (17.3%), and *Piper auritum* Kunth (13.6%). In addition, typical NaF taxa included *Matayba oppositifolia* (A. Rich) Britton (10.6%), *Virola koschnyi* Warb. (10.8%) and *Garcinia intermedia* (Pittier) Hammel (10.5%). Liana coverage was highest in the NaF gaps, while the overall stem density was lowest (Fig. 3).

The second pRDA (Fig. 3) illustrates that when factoring out the effect of MS gap characteristics, the set of typical species for CeF, NaF and CoM gaps were little changed. The fit of species generally decreased, showing that MS gap characteristics explained part of the variation in species abundances. The greatest change was observed in *Cephaelis*: in the second pRDA, the two constrained axes explained only 2.8% of the variation in its abundance.

4. DISCUSSION

Contrary to our expectation, the similarity between the CeF and NaF gaps was lower than that between the CoM and NaF gaps. Furthermore, the low floristic similarity between the CeF and NaF gaps was explained when accounting for the effect of MS gap characteristics (Fig. 3; Tab. III), indicating that the CeF gap conditions were not as favourable for a natural forest composition as the gap conditions in the CoMs. These results suggest that the requirements in CeF management have not helped in minimizing the negative impact of logging on primary forest species. However, since there were a variety of uncontrolled factors involved in the study, this conclusion does not seem inevitable. Below we suggest three factors that may explain the low similarity between the NaFs and CeFs studied.

First, the results may not be directly linked to the current forest management system, but rather reflect past disturbance, which may have been higher in the CeFs than in the CoMs. The clearest difference in MS gap characteristics among the CeFs, CoMs and NaFs was the high density of stems ≥1 cm in dbh in the CeFs (Fig. 3). This was due to a high abundance of pioneer species such as *Cephaelis* sp. and *C. tomentosa* in the CeF gaps. The predominance of light-demanding taxa may be related to structural changes in the forest, resulting from earlier loggings (Bermúdez et al., 2007; Kessler et al., 2005) or from hurricane disturbance (Brokaw and Grear, 1991; Crow, 1980).

Even when the floristic composition in CeFs indicated higher past disturbance, characteristics such as the higher coverage of young and canopy trees in the CeF gaps appeared to indicate reduced levels of logging damage compared with the CoM gaps (as also noted in Kukkonen et al., 2008). This suggests that the increased density of pioneer species may have resulted from disturbance that occurred before certified management practices were initiated. Earlier studies (e.g. Chapman and Chapman, 1997; Primack and Lee, 1991; Sist et al., 2003) have demonstrated that the structural changes caused by selective logging may persist for several decades.

In Río Cangrejal, the first certificate was granted only 12 y ago and during the first years after certification, the criteria were not strictly implemented (Markopoulos, 1999). In an ecological context, the time period may thus have been too short to observe the impacts of improved management practices on floristic composition. The higher similarity between the CoM and NaF gaps may be due to the CeFs having been logged more intensively during past decades and/or for a longer period of time than the CoMs. Certificates of sustainable forest management tend to be granted for such communities that have relatively long histories of commercial forest management (A. Nygren, 2007, pers. comm.). Without available information on the distribution of hurricane damage, we suggest that the CeFs may have been relatively more affected than the CoMs and NaFs, due to their higher mean altitude (Tab. I) (see Brokaw and Grear, 1991).

Second, seed dispersal from agropastoral areas may contribute to the low floristic similarity between the CeF and NaF gaps. Characteristic NaF taxa included typical primary forest species, with canopy trees such as *S. glauca* and *M. oppositifolia* (Cordero and Boshier, 2004; Hartshorn and Poveda, 1991), and typical shade-tolerant species such as *V. koschnyi* (Balderrama and Chazdon, 2005) and *G. intermedia* (Martínez-Garza, 2003). The floristic composition of the CoM gaps was similar to that of the NaF gaps (Fig. 3), whereas the typical taxa of the CeFs included secondary forest or fallow species. *Cephaelis tomentosa* thrives in open and disturbed areas and is rarely found under closed forest canopies (Hartshorn and Poveda, 1991). *Perymenium grande* is a secondary forest tree species that typically grows in open areas (Cordero and Boshier, 2004) and is abundant in fallows (Kass and Somarriba, 1999).

Earlier studies show that recovery of the natural tree species composition after selective logging is largely dependent on the proximity of undisturbed forest areas (cf. Chazdon, 2003). The CeFs of Río Cangrejal are generally located further from Pico Bonito National Park than the CoMs, of which only one is not located in the park's vicinity (Fig. 1). Thus, the CoMs may be relatively more influenced by seed dispersal from the NaFs, whereas in the CeFs, agropastoral and secondary forest species seem to be replacing forest species in the logging gaps. Differences in seed dispersal patterns may also affect species composition; many seed-dispersing animals avoid crossing open areas (Holl, 1999), whereas small wind-dispersed seeds of tree and shrub species that predominated in the CeFs may spread more randomly (Dalling et al., 2002).

Third, the ordination results indicated that a considerable amount of the variation in the floristic data remained unexplained. This suggests that we failed to include some major environmental gradients in the set of MN gap characteristics. In recording the distance between the forests as an MN variable, we probably captured only part of the variation related to the abiotic and biotic factors affecting floristic composition. In particular, soil factors such as fertility, drainage and texture are important determinants of tree species composition in tropical forests (Clark et al., 1999; de Carvalho et al., 2000).

Furthermore, besides above-ground competition for light, below-ground competition for nutrients by lianas (Schnitzer et al., 2005) or surrounding adult trees (Lewis and Tanner, 2000) may limit the survival of some tree species, especially in nutrient-poor soils. Although liana abundance tends to increase with logging intensity (Schnitzer et al., 2004), we observed a lower abundance of lianas in both CeFs and CoMs compared to NaFs. This was most likely due to liana cutting, which is commonly practiced in Río Cangrejal to reduce logging damage (Gerwing and Uhl, 2002). In community-based forest management systems, the differences between CeF and CoM management may in general be relatively small compared to large-scale industrial loggings. Because heavy machinery is not used and logging roads are few, such RIL practices as limiting skid rail damage and road construction do not apply.

5. CONCLUSION

One of the main aims of forest certification is to minimize the negative impacts of logging on the natural floristic composition. However, we found a lower floristic similarity between the CeFs and NaFs than between the CoMs and NaFs in the treefall gaps studied in northern Honduras. Based on the high abundance of pioneer species and gap environmental variables indicating reduced disturbance in the CeFs, we suggest that factors such as past loggings, hurricanes and the location of the forests in relation to seed sources may have a greater impact on forest structure than implementing certified management practices. Therefore, landscape-level planning and restoration of degraded forest species may be important means for more efficient mitigation of the negative impacts of selective logging on forest structure. We recommend that such factors should be considered when planning guidelines for certifying community-based forest operations in the tropics.

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