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Regeneration of commercial tree species in a logged forest in the Selva Maya, Mexico

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ABSTRACT

One of the main threats to the sustainability of community forestry in the Selva Maya is insufficient regeneration of commercial tree species. We evaluated the regeneration status of 22 commercial tree species in a managed semideciduous tropical rain forest in Southern Mexico. The study was carried out in six harvesting areas along a 16-year chronosequence. In each area, 10 transects (1000 m^2) were established and all trees >50 cm height and <10 cm diameter were recorded. We evaluated the relationships between seedling and sapling abundance, and canopy cover and disturbance condition (closed forest, canopy gap, log landing, skid road, primary road and secondary road). The area occupied by closed forest canopy increased with age of harvesting area (65–91% of sampled area), while the area occupied by canopy gaps decreased (22–9%). Log landings occupied less than 1% of the sampled area. The predominant canopy cover was 75–80% in all harvesting areas, even in the most recently harvested areas. The highest densities of seedlings and saplings, of both shade tolerant and intolerant species, were found in log landing and skid trails, followed by secondary roads. Even *Simarouba glauca*, a shade tolerant species, displayed higher densities in sites with ≤65% of canopy cover. Our results support previous findings and indicate that the levels of disturbance caused by existing harvesting procedures may be inadequate to promote sufficient regeneration of not only light demanding desirable species but also for some of the evaluated shade tolerant species of commercial interest. Seedling and sapling densities exhibited by *Swietenia macrophylla*, for example, are insufficient to support current harvesting rates. The application of a spatial mixed system with patch-cuts of different sizes, a consequence of group felling, could be applied to provide the necessary conditions for the regeneration of the main commercial species.

1. Introduction

The Selva Maya contains the largest contiguous tract of tropical forest in Central America (Primack et al., 1998). However, in the Southeast of Mexico, these forests are considered a “hot spot” of deforestation (Turner et al., 2001). In this region, community management of forest is recognized as a successful strategy for conservation of this severely endangered ecosystem (Bray et al., 2003, 2004; Ellis and Porter-Bolland, 2008). Some of the forests in this region are among the oldest tropical forests certified by the Forest Stewardship Council (FSC) for sustainable forest management. Among the factors to ensure the sustainability of these systems, tree recruitment is critical to guarantee the continued regeneration of commercial species and maintain long-term operational viability. This facet of forest management is of vital importance because the high seedling mortality suffered during regeneration ensures high selection pressure of individuals at this time. This can have a profound influence on the composition and diversity of the forest (Whitmore, 1996).

Forests of the Selva Maya region are harvested by selective logging at a lower intensity than in other tropical forests, a practice which favours the regeneration of shade tolerant species (Snook, 1998; Dickinson et al., 2000; Putz et al., 2000a; Hall et al., 2003). Since many of the timber species are high light demanders, their requirements for regeneration may not be adequately met by the current management system. Various reports indicate that selective logging in the area creates gaps of insufficient size and frequency to ensure the regeneration of the shade intolerant main commercial species; mahogany (*Swietenia macrophylla* King) and Spanish cedar (*Cedrela odorata* L.) (Snook, 1996; Whitman et al., 1997; Dickinson et al., 2000). This reduced regeneration adds to the risk of overestimation of overall growth rates in the main commercial species (Snook, 1996).

As part of the diversified management of natural forests, extraction of a wider variety of tree species should be promoted by forest managers (Plumptre, 1990; Pinard et al., 1999). While

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various studies have evaluated the regeneration status of mahogany in tropical forests, the long-term recruitment levels of other current and potentially commercial species remain undefined. Knowledge of the establishment requirements of important commercial tree species is of fundamental importance in order to design more effective management systems for the Selva Maya. Regeneration studies in managed tropical forests have frequently evaluated tree performance in particular disturbance conditions without providing an estimate of the area occupied by these conditions in the forest (e.g. Snook and Negreros-Castillo, 2004; van Rheenen et al., 2004; Grogan et al., 2005; Negreros-Castillo and Mize, 2008). In this work we address this deficit by evaluating the regeneration status of 22 tree species of commercial interest along a chronosequence of logging sites and the area occupied by the various disturbance conditions resulting from logging. The study was conducted in a managed tropical rain forest in the Selva Maya of Mexico. We examined two specific issues: what is the extent of different canopy cover levels along the chronosequence? Are the disturbance conditions created by logging sufficient to prompt sustained regeneration of commercial tree species?

2. Methods

2.1. Study area

The study was carried out in the community-owned (*ejido*) tropical seasonal forest of Tres Garantías, in the state of Quintana Roo (18°12′30″ and 18°05′00″N; 88°52′30″ and 89°07′30″W; 30–120 m.a.s.l.). This forest is incorporated into the Mesoamerican Biological Corridor initiative (Miller et al., 2001; Bray et al., 2004). The forest covers 32,265 ha and is classified as seasonal rain forest (“selva mediana” and “selva baja subperennifolias” *sensu* Pennington and Sarukhán, 2005). It is a dense community, with high richness of tree species and abundant climbers. Trees reach heights of 15 m, and 25–50% of the trees are deciduous (Pennington and Sarukhán, 2005). This forest type occupies approximately 10% of Mexico yet it displays a high rate of deforestation (Bray and Merino-Perez, 2005). The dominant tree species include *Manilkara zapota* (used for extraction of latex) and *Brosimum alicastrum* (Pennington and Sarukhán, 2005). These forests are prone to natural catastrophic disturbances, such as hurricanes (Snook, 1998). Hurricanes play an essential part in the dynamics of the forest; the consequent openings in the forest canopy favour the regeneration of light demanding trees, such as mahogany (*S. macrophylla* King) and the Spanish cedar (*C. odorata* L.). Fires frequently occur after hurricanes, and these also play a role in creating canopy gaps (López-Portillo et al., 1990).

The climate is hot subhumid with abundant rainfall during the summer (June–October) (Aw (x′ i); Köpen classification modified by García, 1976). Mean annual temperature is 26 °C (Escobar, 1981), and mean annual precipitation is 1200 mm. The soils are derived from limestone (INEGI, 1994) and are classified by the locals as: *Tzek' kel*, *Ak'alche*, *Ya'ax hom* and *Serranía*. This Mayan classification has the following equivalence to the FAO/UNESCO system: *Tzek' kel* – Lithosol and Rendzina: shallow soils with stone slabs; *Ak'alche* – Gleysols: low-lying terrains with seasonal inundation; *Ya'ax hom* – Vertisols: lowlands with evergreen vegetation (*sensu* Sánchez-Sánchez and Islebe, 2002). The classification of *Serranía* corresponds to rocky terrain present typically at higher elevations.

The region has a long history of forest management; the present composition of the forests may be the result of the activities of Pre-Columbian Mayan settlement (Gómez-Pompa et al., 1987). From 1953 to 1983 the forests in Quintana Roo were exploited for industrial timber logging through concessions. After this period the local community made the transition to a community forestry enterprise (Galletti, 1998). Since 1953 the system used has been selective logging, focused on two species: mahogany and Spanish cedar. Since 1995 the forest management in this *ejido* has been certified by the FSC and mahogany timber is still the most valuable local forest product. Other species of high commercial value include *Platymiscium yucatanum* and *Cordia dodecandra*.

The selective logging system applied in the area consists of a cutting cycle of 25 years. The total forest harvesting area is divided into 25 harvesting areas and each year 1–3 $m^3\,ha^{-1}$ of the commercial tree species (diameter limits: 35 cm or 60 cm dependent on the species) are removed from each harvesting area. Selected trees which have reached the minimum diameter are felled, creating a single or multiple tree fall gap dependent on the proximity of selected trees. Felled trees are cut into logs and dragged by tractors along skid roads to log landings, where they are piled up. As a result of this process, different types of disturbance conditions are created in the forests with each affecting canopy cover, understorey vegetation and soil.

2.2. Experimental design and data collection

The 22 tree species studied are presented in Table 1, detailing individual shade tolerance guilds and current levels of commercialization. These species are used for both timber and non-timber forest products and include evergreen and deciduous trees. To evaluate their regeneration along a chronosequence, six harvesting areas were selected, each corresponding to the year the area was harvested: 1990, 1993, 1996, 2004, 2005 and 2006. The harvesting areas were chosen based on accessibility and in order to cover a time period of at least 15 years between the oldest and the most recently harvested. The logging intensity could vary among harvesting years depending on existing tree volumes (data not available). This variation could affect the disturbance intensity, and therefore the harvesting sites may differ not only in terms of the time elapsed since logging but also in the extent of the affected area. Due to past management of the entire forest, it was not possible to include a historically undisturbed control area in the analysis. Within each harvesting area, ten 1000 m^2 transects were established. These were 500 m in length, oriented north to south and located a distance of 100 m apart. At either end of each transect, geographic coordinates were recorded with a GPS receiver. On either side of the transect, a 1 m wide strip was delimited, such that in each harvesting site a total area of 10,000 m^2 was sampled. The total area in all six sampled harvesting sites was 270 hectares, yielding an overall sampling intensity of 2%. Each transect was divided into 20 consecutive plots (25 m $\times$ 2 m each) to measure the trees (total of 200 plots per cutting area) and to record the environmental variables. Markers were established every 25 m to delimit the plots and correct for orientation and slope.

Soil disturbance can affect tree regeneration (Denslow, 1995; Dickinson and Whigham, 1999), therefore every 25 m the soil condition was assessed and assigned to one of the following categories: litter present, litter partially removed, litter absent and soil neither rutted nor removed, litter absent and soil deeply rutted and removed. Soil type was classified as either *Tzek' kel*, *Ak'alche*, *Ya'ax hom* or *Serranía*. Low-lying areas or depressions were not sampled because of the low volume of commercially viable species and consequent absence of logging activity.

Number and size category of selected tree species was recorded for each plot. Seedlings and saplings were assigned to one of four categories: seedlings, $\geq$50 cm and $\leq$1 m height; small saplings $>$1 m height and $\leq$5 cm diameter; large saplings $>$1 m height and $>$5 and $\leq$10 cm diameter; and re-sprouts from stumps. The percentage of canopy cover was measured above each tree or group of trees with a spherical densiometer. For trees greater than 1.5 m in height, canopy cover was measured adjacent to the tree.