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Recovery and early succession after experimental disturbance in a seasonally dry tropical forest in Mexico

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ABSTRACT

We studied succession over five years in a seasonally dry tropical forest in Quintana Roo, Mexico, following three different types of experimental disturbance (slashing and complete felling; slashing, felling and burning; and machine-clearing), each one implemented in 1996 on two 0.5 ha treatment plots. Before experimental disturbances, the floristic composition, dominance and diversity of the forest vegetation had been determined. In 1997, after treatments were applied, a second survey characterized early secondary vegetation at one year. A third survey was conducted in 2001. The 1996 vegetation composition revealed no significant differences among the six treatment plots. In 1997, floristic composition on the six treatment plots showed differences in dominance and diversity: the post-treatment vegetation on the slash/fell treatment was clearly distinct from that on the other two treatments. In 2001, differences among the plots had decreased considerably. Comparisons among seral stages revealed that one-year-old secondary vegetation differed from the pre-disturbance original vegetation, while five-year-old vegetation was similar to the original in its diversity, floristic composition and dominance. Felling alone favors species with a high resprouting capacity. The frequency of species with resprouting capacity was lower on slash/fell/burn treatments and lowest on machine-cleared plots. Results indicate that the effect of disturbance tends to decline over time and that complete clearing of small areas is effective as a silvicultural treatment to favor regeneration of valuable timber species and sustain diversity.

1. Introduction

Seasonally dry tropical forests (SDTF) comprise 42% of all tropical vegetation types in the world (Murphy and Lugo, 1995) and suffer severely from deforestation. In Mesoamerica, the original area covered by SDTF was 550,000 km^2 and only 2% are well conserved (Miles et al., 2006). The ever-increasing fragmentation of tropical forests urges the study of the regeneration process in forest ecosystems under timber management. Regeneration process studies can help us to predict which species will colonize disturbed areas, as well as the future species composition in these areas (Westman, 1990).

The ability of species to establish immediately after a disturbance is determined in large part by their presence on the site (as stumps, roots, seeds or seedlings) as well as their capacity to arrive there. The ability of species to maintain themselves as part of a new stand also depends on individual structural characteristics and competitive capacities (Yih et al., 1991; Williams-Linera et al., 1997, 2011; Gaudet and Kaedy, 1988; Vandermeer et al., 2000; Dupuy et al., 2012; López-Martínez et al., 2013). Floristic composition is influenced by the nature of the disturbance (magnitude, frequency and intensity) and the condition of a community when the disturbance occurs (Kellman, 1970). Natural regeneration has been studied more frequently in moist tropical forests than in SDTF (Vieira and Scariot, 2006). In SDTF, species present adaptations to seasonal drought and the regeneration process is relatively rapid, facilitated by the high proportion of small seeds dispersed by wind (Gentry, 1995). Many species are able to resprout after a disturbance event (Ewel, 1980; Murphy and Lugo, 1986; Kennard, 2002; Negreros-Castillo and Hall, 2000; McLaren and McDonald, 2003; Vieira et al., 2006). A relatively simple structure and low diversity (Murphy and Lugo, 1986; Kennard, 2002) give SDTF a high recovery capacity (Vieira et al., 2006).

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Two techniques have commonly been used to study secondary succession: (1) chronosequences and (2) vegetation dynamics studies. Chronosequence studies evaluate changes based on a comparison of various plots of different seral ages, while vegetation dynamics studies document the development of the vegetation in permanent plots, through remeasurements (Chazdon et al., 2007). Most studies in tropical vegetation have been carried out on chronosequences (Westman, 1990; Williams-Linera, 1990; Randall and Pickett, 1992; Snook, 1993; Denslow, 1995; Williams-Linera et al., 2011; Dupuy et al., 2012; López-Martínez et al., 2013). The main disadvantage of these studies is that they use spatially discrete locations to represent changes taking place over time (Pickett, 1989), so data show the net cumulative effect of both spatial and temporal differences. Dynamic vegetation studies examine the gradual shifts over time and can reveal more about ecological processes that produce cumulative changes (Chazdon et al., 2007). Vegetation dynamics studies have been carried out in Mexico (Miranda et al., 1960; Sarukhán, 1964; Sánchez and Islebe, 1999; Valdez-Hernández, 1999) as well as in Central America, notably to document recovery of forests in Nicaragua after hurricane Joan (Vandermeer et al., 1990, 2000; Yih et al., 1991).

In this paper, we analyze the species composition of seasonally dry forest on plots before and after three experimental disturbances: (1) slash and burn; (2) slash and fell; and (3) mechanized clearing. These were applied as silvicultural treatments to favor the regeneration of valuable timber species in managed forests. We evaluated the composition, structure and diversity of regenerating vegetation at one and five years after the treatments.

2. Methods

2.1. Study area

The Yucatan peninsula includes one of the largest continuous tracts of SDTF, making it a priority area for conservation (Miles et al., 2006). Seventy-four percent of Quintana Roo is covered by forest (Díaz-Gallegos et al., 2008). Most of the forest area is under management by Mayan communities (Jhones et al., 2000; Bray et al., 2004). Although Quintana Roo presents the lowest deforestation rate of the Mesoamerican Biological Corridor (0.6% year^{-1}), at least 23% of its territory is covered by secondary vegetation (Díaz-Gallegos et al., 2008). Historically, the forests of the region have experienced human impacts like the traditional slash and burn method of clearing agricultural fields and, more recently, timber extraction (Snook, 1998; Bray et al., 2004). Large scale agricultural clearing and livestock production have affected smaller areas in Yucatan (Jhones et al., 2000). Natural disturbances, notably hurricanes, are also frequent. In the last century at least 100 hurricanes have been recorded as affecting Quintana Roo (Boose et al., 2003). Forest fires are also common. In recent years Quintana Roo was among the ten states with the largest area affected by fire (CONAFOR, 2009, 2010, 2011).

This research was conducted in X-pichil (19°41′ N, 88°22′ W), a Mayan community located in the central region of the Mexican state of Quintana Roo (Fig. 1). The community controls an area of 31,314 ha, of which nearly 30,000 ha have been defined as production forest. These forests are included within the Calakmul-Sian Kaán portion of the Mesoamerican Biological Corridor (Díaz-Gallegos et al., 2008). Floristic richness at the local scale is between 80 and 120 tree species per hectare (Cortés-Castelán and Islebe, 2005; Sánchez et al., 2007).

The dominant soils are lithosols associated with rendzinas and luvisols (CEEM, 1987). The climate is sub-humid warm with a summer precipitation regime (García, 1988). The mean annual temperature is 27.3 °C, and the mean annual precipitation is 1035.6 mm. The study area has a dry-warm season between February and May, and a rainfall season between June and October (INEGI, 1990). Based on the precipitation and temperature regime, the vegetation can be classified as Seasonal Dry Tropical Forests (Murphy and Lugo, 1995).

Local communities produce corn and associated crops on fields cleared using slash and burn methods, felling the understory with "machetes" and large trees with axes, leaving the vegetation to dry. Once dry, the vegetation is burned before the rainy season. The area is usually used for agriculture for one to three years and allowed to fallow for 7–15 years, depending on land availability. Local agriculture is subsistence-oriented and agricultural fields or "milpas" average about one hectare in size (Faust, 2001). Forest extraction began in the seventeenth century and focused on the extraction of large individuals of mahogany (*Swietenia macrophylla* King) (Snook, 1998). Since 1950 hardwood species have also been exploited in X-pichil, originally to make railroad ties, notably 'chechen' (*Metopium brownei* (Jacq.) Urb.), 'jabin' (*Piscidia piscipula* (L.) Sarg.), 'chakte-kok' (*Simira salvadorensis* (Standl.) Steyerm.), 'chakte-viga' (*Coulteria platyloba* (S. Watson) N. Zamora), 'yaxnik' (*Vitex gaumeri* Greenm.), 'boop' (*Coccoloba spicata* Lundell), 'catalox' (*Swartzia cubensis* (Britton & P. Wilson) Standl.), 'tzalam' (*Lysiloma latisiliquum* (L.) Benth.), 'pucte' (*Bucida buceras* L.), and 'kaniste' (*Pouteria campechiana* (Kunth) Baehni) (Murphy, 1990). The study site is located in the production forest of the X-pichil ejido. The vegetation prior to the disturbances consisted of more than 100 tree species (Murphy, 1990; Valdez-Hernández, 1999; Sorensen, 2006). According to local residents, the trees were at least 50 years old. A detailed description of the study area can be found in Snook and Negreros-Castillo (2004).

2.2. Sampling design and treatments

2.2.1. Pre-disturbance sampling

Early in 1996, six treatment plots of 5000 m^2 each (50 m N–S × 100 m E–W) were laid out in well conserved forest vegetation. Distances between plots were less than 500 m, and soil and environmental conditions were similar. In each treatment plot, two sample plots of 500 m^2 (50 × 10 m) were established. In these sample plots, before the clearing treatments were carried out, floristic composition was sampled in the following subplots: arboreal layer (dbh ⩾3 cm) in two sample plots of 500 m^2; seedling layer (10 cm ⩽ height < 1 m) in five randomly selected subplots of 1 m^2. For each individual, species, life-form, and dbh were recorded. In addition, the number of individuals of each species per plot was estimated. Density was estimated considering genets as one individual if the multiple stems were rooted in one subplot. Once all the vegetation data was recorded, two treatment plots received each of the three experimental disturbances described below, applied as silvicultural treatments to regenerate valuable timber species (see Snook and Negreros-Castillo, 2004):

- Slash and Burn (B): slashing of understory vegetation and manual felling of trees. After drying for several weeks, the debris was burned, the treatment used locally to open agricultural clearings.
- Slash and Fell (F): this treatment included slashing and felling, but debris was left on site.
- Machine clearing (M): tree farmers or Caterpillar tractors were used to knock over trees and underbrush, uprooting them and pushing them to the side of the plot, leaving the soil free of vegetation.

2.2.2. Post-disturbance sampling

In 1997 and 2001, post-disturbance regeneration was sampled on two permanent sample plots of 100 m^2 (10 × 10 m) laid out