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Lacandon Maya forest management: Restoration of soil fertility using native tree species

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ABSTRACT

In southern Mexico, where rainforests are being degraded rapidly, the Lacandon Maya use an agroforestry system that both restores and conserves the rainforest. Their system cycles through field and fallow stages that produce food, medicines, and raw materials, and regenerates tall secondary forest. This investigation identified plants managed by Lacandon to restore soil fertility during fallow. Through interviews, Lacandon identified 20 plants managed for forest restoration. Leaf litter measurements and soil samples were taken near two of these species, *Ochroma pyramidale* and *Sapium lateriflorum*. Leaf litter increased quicker beneath *O. pyramidales* compared to other tree species ($R = 0.48$, $P = 0.004$), and total nematode concentrations increased with distance from this tree ($R = 0.71$, $P < 0.001$). Together, these two findings indicated an inhibition of degradation that permits accelerated soil organic matter accumulation. Available phosphorus (P) concentrations beneath *S. lateriflorum* were 16% higher than outside the canopy ($P = 0.03$), and increased with age of the tree, indicating P recovery from subsoil. Our research shows that the Lacandon are cognizant of the natural abilities of certain species to fulfill the restoration needs in their systems. It demonstrates that Maya agroforestry and local knowledge could contribute to efforts to conserve and restore rainforests, and reduce deforestation by accelerating fallow in tropical agriculture.

1. Introduction

Land areas of southern Mexico are being deforested and losing productivity at alarming rates. In Chiapas, Mexico, deforestation is claiming 7% of the forest each year, and erosion has moderately degraded 10% to 25%, and severely degraded 5% of the arable soil (Howard and Homer-Dixon, 1996). These problems are endemic throughout the tropics, as increasing population densities stress the environment through demands on agricultural land (Lal, 1995; Alvarez and Naughton-Treves, 2003). Because these areas are experiencing high population growth and movement (Ram, 1997), these problems will be magnified in future years.

Displaced and migrant populations, in particular, have had a large effect on the ecological stability of this region (Nicholson et al., 1995; Atran, 1999; Mas and Puig, 2001). Land

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management of these groups tends to take the form of cattle pasture (Mas and Puig, 2001; Durand and Lazos, 2004) or short-term *milpa* (O'Brien, 1998). Uncontrolled grazing leaves the land compacted and incapable of production, even for grazing, after a very short time (Garciaoliva et al., 1994; Durand and Lazos, 2004). Following crop and cattle production, these areas do not return to a mature, enriched forest, but to degraded grass and brush vegetation. These lands have very little productive use and relatively low biodiversity (Miller, 1999). Lands devastated by inappropriate use intensify the demand for new lands, leading to further deforestation and social conflict (Nicholson et al., 1995; Howard and Homer-Dixon, 1996).

Ecosystem management and restoration in this area of the world is a complex social, economic, and ecological problem (Nicholson et al., 1995). Tools that offer monetary incentives or sustenance may be important to any long-term solution to rainforest loss and restoration (Nicholson et al., 1995; Foroughbakhch et al., 2001; Li, 2004). Numerous researchers state the importance of recording indigenous knowledge to better understand sustainable land management (Fox et al., 2000; Long and Zhou, 2001; Hardwick et al., 2004). Because indigenous swidden agroforestry systems can be productive (Long and Nair, 1999) while maintaining their ecological integrity (Wang and Young, 2003), swidden practices could contribute to better land management in the tropics (De Clerck and Negreros-Castillo, 2000; Fox et al., 2000). The Lacandon Maya, an indigenous group that has met subsistence needs while maintaining both secondary and primary forests for centuries in southern Mexico, combine forest restoration and domestic production (Nations and Nigh, 1980; Levy, 2000; Diemont and Martin, 2005).

The Lacandon land management system cycles through three field stages starting with the *milpa*, progressing to the *acahual* (low secondary forest), and then to tall secondary forest, before returning to the *milpa* (Nations and Nigh, 1980; McGee, 2002). Neighboring primary forest is conserved to maintain a biodiverse seedbank (Quintana-Ascencio et al., 1996). Ecological succession drives the conversion between field stages (Levy and Aguirre Rivera, in press). From the viewpoint of ecological succession, the *milpa* represents early successional grasses, the *acahual* represents the shrub or early woody stage, and the forest is the climax stage. The *milpa*, or early successional stage, is a polyculture field that includes 20–30 cultivated species. The acahual and forest stages are also productive, offering over 50 plant species used by the Lacandon (Nations and Nigh, 1980). By selecting for certain species and managing the natural succession of the *acahual* and forest stages, the Lacandon are able to restore soil fertility and regenerate secondary forest following the *milpa* stage in less than 20 years (Diemont and Martin, 2005).

Lacandon Maya agroforestry is ecological engineering as described by Odum et al. (1963), where the technology available from natural systems is dominant, and human engineering is supplementary rather than primary. The Lacandon rely on the regenerative capacity of nature. They seed certain plants during the fallow and eliminate others, but in general allow the system to develop without intervention, permitting forcing functions such as sun, wind, and rain to drive the system (Diemont et al., 2006). Furthermore, the Lacandon system is as Mitsch and Jorgensen (1989) have described ecological engineering—designed for the benefit of both humans and the environment. At all stages of successional development, the Lacandon recover harvestable foods, medicines, and raw materials (Nations and Nigh, 1980). This production does not come at the cost of ecosystem health. The system largely self-designs and develops in biodiversity and complexity (Nations and Nigh, 1980; Levy, 2000); numerous animals are drawn to the richness of this ecosystem (Nations and Nigh, 1980).

Previous studies have identified plants that the Lacandon may be using to restore soil fertility (Levy, 2004; Levy and Golicher, 2004). The presence of *Ochroma pyramidale* Urban, has been related to greater leaf-litter (Levy, 2004; Levy and Golicher, 2004) and soil organic matter accumulation (Levy and Golicher, 2004), indicating that the Lacandon manage their fallow to accelerate regeneration of soil fertility. An evaluation of soil chemistry, soil nematode populations, and plant community in all field stages of the Lacandon system revealed seven plants that correlated positively with improved soil conditions (SAW Diemont, JF Martin, and MF Quigley, unpublished data in review). *Hampea stipitata* S. Watson, found in the *acahual*, correlated with elevated soil organic matter concentrations. *Sapium lateriflorum*, found in secondary and primary forest, correlated with elevated ammonium and nitrate concentrations. *Cecropia obtusifolia* Bertol., discovered in *milpa*, *acahual* and secondary forest, and *Piper auritum* H.B.K., in *acahual* and secondary forest, correlated with higher bacterivorous nematode concentrations. These results encouraged additional research into the plants the Lacandon are using during the fallow to restore secondary forest. The objectives of this study were to: (1) through interviews, determine if the Lacandon have selected for certain species to accelerate the regeneration of soil fertility; (2) better identify the contribution of selected species (i.e. *O. pyramidale*) to soil fertility; (3) identify the mechanism by which selected species regenerate soil fertility; and (4) evaluate the potential for these methods to be used to restore and conserve tropical rainforests.

2. Materials and methods

Interviews and soil sampling were conducted in Lacanja Chansayab, Chiapas, Mexico. Lacanja has a population of approximately 400 and is one of three major communities of the Lacandon Maya. Lacanja is located in Chiapas, the southern-most Mexican state, at 16°45′ 30″N and 91°08′ 30″W and at an elevation of 400 m. The predominate soil type is Luvisol (INEGI, 1982), with a clayey texture and neutral pH. The surrounding ecosystem is tall moist forest, and annual rainfall is 2500 cm (Guillen-Trujillo, 1998).

2.1. *Interviews*

Interviews were conducted with five Lacandon farmers to determine what plants they regarded as important for fertility regeneration during the fallow stages of the system. Farmers were asked first to identify what plants were good for fertility regeneration in the fallow. They were asked if soil that resulted in the area where the plant was located would be good, whether the plant leaf litter produced good compost, whether the *milpa* stage that may follow in the location would