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Logging in bamboo-dominated forests in southwestern Amazonia: Caveats and opportunities for smallholder forest management

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ABSTRACT

Guadua sarcocarpa and *Guadua weberbaueri* (Poaceae: Bambuseae) have a negative influence on tree regeneration and recruitment in bamboo-dominated forests of southwestern Amazonia. The lack of advanced regeneration and sparse canopy in this forest type present a considerable challenge for developing sustainable timber management plans. We conducted field studies in the Porto Dias Agroextractive Settlement Project in Acre, Brazil to assess influences of logging in bamboo-dominated forest sites. Taxonomic composition, stand structure, aboveground biomass, commercial timber volume, and commercial tree seedling and bamboo culm density were compared between five logged vs. unlogged sites in different landholdings, using modified 0.5 ha Gentry plots. No differences in taxonomic composition, aboveground biomass, adult and juvenile stem density, or woody seedling and bamboo culm density were detected between paired logged and unlogged sites. Commercial timber volume, however, was reduced by almost two-thirds in logged plots, suggesting that long-term timber management goals in this forest type are compromised since so few future crop trees remained onsite. Our findings indicate that in order to maximize local management objectives, community forest managers must approach logging in bamboo-dominated forests with caution. We suggest an integration of non-timber forest product extraction with low harvest intensity and low-impact logging, tending of natural regeneration, and diversification of commercial species.

1. Introduction

There is substantial debate in the scientific community on exactly what constitutes "sustainable timber management" in the tropics, since many large trees are often removed in the first harvest cycle (Rice et al., 1997; Bowles et al., 1998; Pearce et al., 2003; Sist and Ferreira, 2007; Zarin et al., 2007). Particularly challenging are forests that differ from the idealistic tall, closed-canopy stands of trees (e.g., Mostacedo et al., 1998; Toledo et al., 2001), for which many current logging guidelines were developed (see Pinard et al., 1995; Dykstra and Heinrich, 1996). Forests prone to disturbances (wind damage, fire, logging), or characterized by a discontinuous canopy, create ideal settings for aggressive pioneer plants, such as lianas (Putz, 1991; Gerwing, 2001; Schnitzer et al., 2000), or bamboos (Griscom and Ashton, 2006; Veldman et al., 2009; Larpkern et al., 2011; Medeiros et al., 2013), potentially limiting regeneration and recruitment of commercially valuable tree species. As such, the likelihood of high-grading, or removal of the majority of desirable commercial stems, is increased. Especially for locally rare species, e.g., *Tabebuia* spp. and *Hymenaea courbaril* (Bignonaceae and Fabaceae, respectively; Schulze et al., 2008a), or those exhibiting slow growth rates, e.g., *Tabebuia* spp. (Schulze et al., 2008b), residual stand recovery may take many decades (Zarin et al., 2007). Dauber et al. (2005) determined that even with a low harvest intensity (11.8 m^3 ha^{-1}) and implementation of reduced-impact logging (RIL) techniques, only 22% of the original harvest volume will be replaced in 25 years in a liana-dominated forest in Bolivia. While a recent global meta-analysis of more than 100 case studies estimated a doubling of these replacement volumes to an average 54% for the next harvest (Putz et al., 2012), it is clear that recovery of tropical timber volumes under current cutting cycles is not feasible.

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The arborescent bamboo [*Guadua sarcocarpa* Londoño and Peterson and *Guadua weberbaueri* Pilger (Poaceae: Bambuseae)]-dominated forests of southwestern Amazonia are characterized by typically low tree basal areas (Nelson, 1994; Silveira, 2001; Griscom, 2003) and varying *Guadua* culm densities, from low-density scattered culms in *terra firme* forests to stands with an average of 2000 culms ha^{-1} (Londoño and Peterson, 1991; Vidalenc, 2000; Vieira et al., 2005). The two most common species of *Guadua* in southwestern Amazonia, *weberbaueri* and *sarcocarpa*, have tall (~10–20 m) culms that are 8–10 cm in diameter (Londoño and Peterson, 1991). Approximately 161,500 km^2, including the departments of Madre de Dios, Peru, Acre, Brazil, and Pando, Bolivia, is covered by this forest type (Carvalho et al. 2013). Tree species diversity is up to 60% less than forest patches without bamboo, with a tendency towards dominance by pioneer taxa of little commercial value (Silveira, 2001; Griscom et al., 2007). Given *Guadua*'s rapid growth rate (up to 10 cm day^{-1} in height in the rainy season), its interconnected rhizome network, and its ability to use neighboring trees for support (Fig. 1; Silveira, 2001; Griscom and Ashton, 2006), anthropogenic disturbances tend to enhance its competitive advantages. In other bamboo-dominated forests, bamboo species have been observed to flourish following human disturbances, resulting in a decrease in woody species abundance, richness, diversity, regeneration, and basal area (Whitmore, 1984; Campanello et al., 2007; Larpkern et al., 2009, 2011), all important criteria for sustainable timber management (Putz et al., 2001). D'Oliveira et al. (2004) concluded that of the three major forest types in the Antimary State Forest in Acre, Brazil, bamboo-dominated forest had the lowest timber management potential and suggested that it should only be logged under special circumstances.

Bamboo-dominated forests in this region are a good example of an ecosystem that requires greater taxonomic focus and special management considerations. Relatively few papers have specifically addressed floristic composition (but see Silveira, 2001; Griscom et al., 2007), and indeed, earlier studies tended to disregard *Guadua*-dominated forests as a distinct forest type (see Phillips et al., 1994). This omission may have been the result of the physically impenetrable nature of this particular ecosystem (thus hindering collection expeditions) and the difficulty of distinguishing bamboo-dominated and secondary forests via previous, more limited remote sensing technology (Griscom, 2003; Phillips et al., 2003).

Fig. 1. *Guadua* sp. culm using tree trunk for support via modified branches.

Despite the management complications, bamboo-dominated forests have long played an important role in providing ecosystem services and products for forest residents in southwestern Amazonia. Many forest residents in the Brazilian state of Acre prefer to hunt game animals in this forest type (L. Salgueiro, *pers. comm.*), favor burning areas of bamboo prior to planting subsistence crops such as manioc, corn and beans (Silveira, 2001), and often use bamboo culms for support beams in their houses. Additionally, many animal species prefer bamboo stands, especially during mast fruiting episodes (Silveira, 1999), or are outright obligate bamboo specialists (see Conover, 1994; Kratter, 1997). Even though densities of cash-generating NTFP species such as rubber (*Hevea brasiliensis*, Euphorbaceae) and Brazil nut (*Bertholletia excelsa*, Lecythidaceae) in *Guadua*-dominated forests may be low (Griscom et al., 2007), rubber tappers reportedly favor the quality of latex in bamboo-dominated forests (Silveira, 2001).

Many Amazonian forest-based communities have shifted from local economies based predominantly on NTFPs to those that integrate timber extraction (Kainer et al., 2003; Guariguata et al., 2010; Duchelle et al., 2012; Shanley et al., 2012). To mitigate the much greater ecological impacts which typically ensue from timber vs. non-timber extraction, experimentation is needed, particularly given efforts to curtail carbon emissions that typically increase with logging activities (Putz et al., 2008b; Blanc et al., 2009). Few field datasets for the characterization of aboveground biomass (AGB) exist from this forest type, but typically, *Guadua*-dominated forests have considerably lower AGB values (224 Mg ha^{-1}) than other forest types in the region (322 Mg ha^{-1} for dense forest) (see Vieira et al., 2005; Salimon et al., 2011; D'Oliveira et al., 2013). Nonetheless, their conservation could eventually benefit forest communities through financial compensation from reduced emissions due to deforestation and degradation (REDD) programs (Hall, 2008), as retaining forest carbon is one of many incentives for improving management practices in tropical forests (Putz et al., 2008a). Information on short-term logging impacts on AGB would be valuable to assess how timber management may impact carbon stocks in this forest type (see D'Oliveira et al., 2013).

We present results of a field investigation of logging and management impacts in bamboo-dominated forest sites in southwestern Amazonia. Our objectives were to assess the effects of current conventional logging practices on forest stand structure, timber and NTFP tree seedling densities, and woody plant taxonomic composition. We hypothesized that AGB, commercial timber volume, BA, juvenile and sub-adult tree stem density, and timber species density would all be reduced in logged forest, while there would be an increase in heliophilic genera density in the seedling size class (⩽1 m height), and bamboo culm density due to post-logging canopy openness.

2. Methods

2.1. Study site

The study was conducted in the Porto Dias Agroextractive Settlement Project (S 10°00′39, 9″, W 66°46′26,4″), a 22,145 ha tract of seasonally-moist tropical forest, subsistence agricultural fields and pasture in the Brazilian state of Acre. The landscape is defined by red–yellow latisols of low fertility and gently-rolling to flat topography, with mean annual rainfall and temperature of 1655 mm yr^{-1} (Perz et al., 2013) and 24.5 °C (Vieira et al., 2005), respectively. The Settlement retains a high proportion of forest cover (80%; Franco and Esteves, 2008), most of which is dominated