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# Regeneration and management of lesser known timber species in the Peruvian Amazon following disturbance by logging

Rune Juelsborg Karsten [a,b,*], Henrik Meilby [a], Jørgen Bo Larsen [c]

[a] Department of Food and Resource Economics, University of Copenhagen, Rolighedsvej 25, 1958 Frederiksberg C, Denmark
[b] The International Woodland Company, Amalievej 20, 1875 Frederiksberg C, Denmark
[c] Department of Geosciences and Natural Resource Management, University of Copenhagen, Rolighedsvej 23, 1958 Frederiksberg C, Denmark

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ABSTRACT

Following the principles of Reduced Impact Logging (RIL) the construction of roads and log landings together with logging gaps are the most profound direct impacts that a forest operation has on the forest. While the effects of logging gaps have been studied in detail, the impacts of road and log landing construction, and how the forest regenerates after such disturbances, remain poorly understood. This paper investigates the regeneration success of a range of well/lesser-known timber species in a tierra-firme forest concession in Peru. Sample plots (100 $m^2$) were established in areas with three different types of logging induced disturbances: skid trails caused by log extraction, secondary roads and log landings/patios. Seedling establishment of 16 different commercially targeted species groups was examined for these three types of disturbances using a chronosequence of 5 years. As 100 plots were inventoried for each type of disturbance an area of 3 hectares was sampled in total. The regenerative success was compared across disturbance categories, and each species' response to environmental variables was investigated using zero-inflated negative binomial regression. Regenerative success varied across species groups, with the majority either regenerating significantly better at the least disturbed sites ($n = 6$) or showing statistically indistinguishable results ($n = 9$) because of limited regeneration. One species group, *Cariniana* spp., regenerated best at intermediate sites. The varying response across species groups indicates a need for a more varied forest management. For species with poor regeneration it is recommended to plant saplings (enrichment planting) to ensure forest recovery and species preservation at the landscape level.



## 1. Introduction

Logging is, besides forest clearing, one of the most destructive interventions that humans can apply in tropical forests. Logging can significantly alter the forest microclimate and, depending on the intensity, make the forest vulnerable to natural disturbances such as wind and/or fire (Cochrane, 2003). Reduced Impact Logging (RIL) has been introduced to minimize damage to the residual stand caused by logging operations (Dykstra, 2002; Putz et al., 2008, 2000). Studies have found that half of the disturbance caused by logging is the direct impact resulting when felling a tree, the rest of the disturbance is the result of skidding, bucking and transport of the logged tree (Johns et al., 1996; Pereira et al., 2002). Other studies have found that the majority of the disturbance associated with handling of the log, derives from skidding (Asner et al., 2004), and that even carefully planned logging directly disturbs as much as 25% of a stand (Jackson et al., 2002).

It can be argued that construction of roads and timber landings/patios are more damaging operations at a local scale than removal of single trees using RIL guidelines. Disturbances caused by logging operations vary in size (spatial coverage) and severity, and range from the larger patios to the relatively smaller disturbance from skid trails. Construction of roads and patios implies that any woody material is removed prior to the construction and, in addition, roads are often paved with gravel and maintained with heavy machinery, thus compacting the soil. Similarly, patios are subjected to soil compaction by heavy machinery, but here the damage is exacerbated by the handling and storage of logs. This gradient of disturbances provides a valuable opportunity to study the regenerative ecology of a range of important tree species and their response to varying degrees of disturbance. The impacts that

* Corresponding author at: Department of Food and Resource Economics, University of Copenhagen, Rolighedsvej 25, 1958 Frederiksberg C, Denmark. Tel.: +45 2859 8779; fax: +45 3533 6801.
*E-mail address:* runejk@ifro.ku.dk (R.J. Karsten).

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these disturbances have on the forest have not been studied much, or are at least rarely described in the literature (Fredericksen and Mostacedo, 2000; Nabe-Nielsen et al., 2007; Soriano et al., 2012; Toledo-Aceves et al., 2009). By contrast, the large volume of studies focusing on canopy gaps is disproportionate to the amount of disturbance they actually represent (Hartshorn, 1978; Hubbell, 1999; Kukkonen and Hohnwald, 2009; Kukkonen et al., 2008; Schnitzer and Carson, 2001; Schwartz et al., 2012). While there is a consensus that logging affects the ecological processes, the actual impact remains largely unknown (Clark and Covey, 2012; Dickinson et al., 2000; Soliz-Gamboa et al., 2012). Quantifying the disturbances and understanding how the forest regenerates after disturbances is a practical starting point. At this stage no such knowledge exists for even the most extracted timber species (Guariguata and Pinard, 1998; Park et al., 2005; Peña-Claros et al., 2008b). In many conditions light is likely to be a key limiting factor for seedling establishment and survival (Augspurger, 1984), but studies have found that the availability of light is not the only important determinant for species regeneration. Factors such as leaf litter (Molofsky and Augspurger, 1992; Nabe-Nielsen et al., 2007) and mechanisms related to density-dependent mortality patterns according to the Janzen–Connell hypothesis, seed predation (DeMattia et al., 2004), and pest attacks (Alvarez-Loayza and Terborgh, 2011; Metz et al., 2010) also affect regeneration success.

Over the last 10 years the exploitation of secondary timber species in the Peruvian Amazon, such as Shihuahuaco (*Dipteryx micrantha* Schreb.), Tornillo (*Cedrelinga catenaeformis* Ducke) and Cachimbo (*Cariniana* sp. Casar) surpassed the exploitation of classic timber species such as Spanish Cedar (*Cedrela odorata* P. Browne) and Mahogany (*Swietenia macrophylla* King) (Putzel et al., 2011, 2008; Rios Torres, 2003). With the shift in exploitation focus, logging companies have started to harvest a new generation of lesser known species. The knowledge of these species' ecology as well as their role in the ecosystem is poor (e.g. Mostacedo and Fredericksen, 1999; Park et al., 2005). This lack of knowledge could result in best-management practices based on wrong assumptions, not favoring the logged species in the management, and thus compromising the long term sustainability in production forests. It is, thus, completely unknown if the prescribed management guidelines for a sustainable forest management, actually ensures the long-term survival of the harvested species at a landscape level.

Increasing the ecological knowledge on a range of the lesser-known timber species is of increasing economic importance. Such knowledge is important for designing and implementing guidelines for sustainable forest management, combining economic returns with ecosystem and biodiversity protection as well as social responsibility. A basic requirement for the exploited species to maintain reasonably large and spatially well-distributed populations in the long term is that they regenerate successfully after logging. Studying the impact of varying disturbance conditions on the regeneration of lesser-known species would provide a better understanding of how these interventions tend to affect the species and thus how successfully the forest regenerates after logging. Therefore the objective of this study is to examine the regeneration of a range of timber species for varying levels of disturbance.

## 2. Methods

### 2.1. Study area and logging infrastructure

The study area is located in tropical moist forest (Holdridge Life Zone System, Holdridge (1947)) in the Cohengua River Basin of the region of Alto Ucayali, Peru. Research was conducted in the Consorcio Forestal Amazonico's (CFA) concession (South: 10° 22′; West: 73° 48′). The concession consists of 180,508 hectares of forest, 89% of which are productive areas, while the remaining 11% are unmanaged high conservation value forest areas.

The average annual temperature is 25.7 °C, ranging from 24.3 °C (August) to 26.4 °C (November), and the average rainfall is 2000 mm. The rainy season is from September to April, and the dry season starts in May and last till September (Tosi, 1960).

Organized forest logging did not take place before the creation of the concession in 2004, and the majority of the concession is thus untouched pristine forest. The occurrence of large individuals of *Cedrela odorata* also indicates that the forest has not been previously logged. The forest type is Tierra Firme, and such forests are among the most abundant forest types in newly established logging concessions.

On average the standing timber volume is estimated at 160 $m^3$ $ha^{-1}$, with a commercial standing volume of 30–35 $m^3$ $ha^{-1}$. The applied logging intensity is 12 $m^3$ $ha^{-1}$ $year^{-1}$. The prescribed cutting cycle is 30 years, and the whole concession is therefore divided into 30 annual management units (Parcela de Corta Anual, PCA's). Since 2007 the concession has been certified by FSC (Forest Stewardship Council) assuring, among other requirements, that logging is practiced through Reduced Impact Logging (RIL) techniques (Dykstra, 2002; Pearce et al., 2003; Peña-Claros et al., 2008a, 2008b; Sist et al., 1998).

Three types of logging infrastructure, characterised by different degrees of disturbance, were sampled:

#### 2.1.1. Skid trails

These are the trails resulting when the trunk of a felled tree is extracted to a secondary road using a skidder. The wheels of the skidder create tracks where the disturbance is most profound. The tracks are characterised by soil compaction and to some extent exposure of the mineral soil. The canopy layer above the skid trails is usually unaffected, and the existing ground vegetation remains largely intact. Skid trails are on average 4 meters wide.

#### 2.1.2. Secondary roads

These are the roads where logs are brought to by skidders. They are used for further transportation by truck. The roads are prepared with gravel. Any existing ground vegetation is removed and significant soil compaction is caused by the transportation. The canopy is opened up, and the road surface is exposed to direct sunlight, causing partial disruption of the forest microclimate. During rainstorms significant erosion of road material can occur. Secondary roads are on average 8 m wide.

#### 2.1.3. Patios

These are the areas where trucks unload logs that have been transported using the secondary road network. The patios are larger openings in the forest, where logs are organized and prepared for further transportation by truck. Patios vary in size, but are about 1 ha on average. There is no canopy cover in the patios and all ground vegetation is removed. The exposed soil, a mixture of organic and mineral soil, is severely compacted due to the operation of heavy machinery (McNabb et al., 1997). The forest microclimate is destroyed, and the site is exposed to direct solar radiation, as well as erosion following rainstorms (Uhl and Kauffman, 1990).

The three different types of logging infrastructure can be ranked with regard to loss of forest microclimate. The skid trail is a disturbed site type, but with a close-to-intact forest microclimate. Secondary roads are larger disturbances with removal of organic soil layer; however, the intact forest is never more than four meters away from the centre of the road. Patios are even more heavily disturbed where the forest microclimate is completely eliminated. The distance from the centre of the patio to the intact forest may be 50–100 m.