Forest Ecology and Management 367 (2016) 71–79

Contents lists available at ScienceDirect

Forest Ecology and Management

journal homepage: www.elsevier.com/locate/foreco

Effect of reduced-impact logging on seedling recruitment in a neotropical forest

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ARTICLE INFO

Article history:
Received 4 October 2015
Received in revised form 15 February 2016
Accepted 17 February 2016

Keywords:
Guyana
Regeneration
Forest disturbance
RIL
Sustainable forestry
Timber

ABSTRACT

Seedling growth and survival are critical for tropical rainforest regeneration. Alterations to natural disturbance regimes, such as those brought about by logging, have the potential to shift relative species abundances and the community composition of forests, resulting in population declines for commercially valuable species. Timber operations therefore need to minimise such changes if long-term sustainability is to be achieved within the industry. Reduced-impact logging (RIL) has been promoted widely as an alternative management strategy to conventional selective logging, as it employs practices that decrease the negative impacts of logging within forests. However, the long-term sustainability of RIL, including the influence it has on the regeneration of species targeted for timber extraction, is still uncertain. Here we undertake a comparative study in Iwokrama forest, Guyana, examining seedling densities of four commercially valuable and two pioneer tree species in unlogged, 1.5 years and 4.5 years postharvest forest plots to ascertain how seedling regeneration is effected by RIL. We find that RIL had either a neutral or positive impact on the density of seedlings of timber species when compared to unlogged forest, with pioneer species densities remaining rare. We conclude that the forestry practices associated with RIL have little effect on the natural regeneration rates of key commercially valuable tree species in logged neotropical forests.

1. Introduction

Logging rates throughout the world's tropical rainforests continue to increase (Arets, 2005; FAO, 2010; Gardner, 2010) with approximately 30% of their areal extent designated for timber and non-timber product exploitation (FAO, 2010). Indeed, over 40 million hectares are currently allocated to selective logging globally (Asner et al., 2009; Blaser et al., 2011). In tropical forests, seedling growth and survival are driven principally by small-scale disturbance dynamics of canopy gaps (Brokaw, 1982; Hartshorn, 1978; ter Steege et al., 1994; Zagt, 1997). When a tree falls, either naturally or through logging, a canopy gap is created of varying size. The resultant gap alters the microclimate (light, moisture, and temperature) of the immediate area, stimulating the growth of any seedlings already present (climax species) or triggering seed germination (pioneer and climax species) (Yamamoto, 2000). Changes to natural disturbance regimes, such as those brought about by logging, can thus affect the growth, survival and reproduction rates of plant species (Asner et al., 2004; Boot, 1996; Brokaw, 1982; de Avila et al., 2015; Fenner, 1985; Karsten et al., 2014; Rose, 2000; ter Steege and Hammond, 2000). Consequently, forest assemblage composition can alter over time, due to species-specific variation in re-establishment following logging (Asner et al., 2004; Karsten et al., 2014; ter Steege et al., 2002) and applied silvicultural practices (de Avila et al., 2015). Low disturbance levels tend to favour slower growing hardwood climax species, resulting in relatively stable forest ecosystems that characterise lowland tropical rainforests. As disturbance levels rise, faster growing, less dense pioneer species tend to dominate (Karsten et al., 2014; ter Steege and Hammond, 2000). Therefore, the extent to which rainforest structure and composition are impacted by logging is highly dependent on the intensity of logging, harvest interval, and management practices implemented (Gardner, 2010; Waide and Lugo, 1992; Zagt, 1997).

Reduced-Impact Logging (RIL) was developed to provide a more sustainable alternative to conventional selective logging, whereby the detrimental effects inherent in many traditional forestry operations are minimised (Pinard and Putz, 1996; Putz et al., 2008). Although the forestry techniques used under RIL vary from country to country, the aim is to retain forest canopy integrity and species diversity (Edwards et al., 2011; Gibson et al., 2011; Putz et al., 2012), reduce land degradation (Bryan et al., 2010; Dykstra, 2002; Dykstra and Heinrich, 1992, 1996; Jonkers, 2002; Putz

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http://dx.doi.org/10.1016/j.foreco.2016.02.022

et al., 2008), and decrease the carbon emissions associated with collateral damage to surrounding vegetation and soil disturbance (Pinard and Putz, 1996; Putz et al., 2008), while maintaining a sustained timber supply for future cutting cycles (Putz et al., 2000). Tree inventories are undertaken in order to plan the most efficient and least destructive extraction of logged timber and, in some operations, selected harvest trees have attached vines cut several months prior to removal. The trees are then felled using directional techniques in order to facilitate extraction and minimise stand damage, with logs removed using a skidder and winch.

In this study, we examine natural regeneration levels of commercially valuable tree species in a RIL logging operation in Guyana. Guyana's commercial timber species occur in isolated stands dominated by one or two species (Johnston and Gillman, 1995). Harvesting operations are therefore selective by necessity with extraction rates averaging 2–3 trees/ha^{-1} (Blaser et al., 2011; Jonkers, 2002; van der Hout, 1999), although they can be as high as 20 trees/ha^{-1} in some areas (Jonkers, 2002). While the countries annual rate of 0.3% deforestation is relatively low compared with other tropical countries (FAO, 2006), timber constitutes an important component of the national economy (Blaser et al., 2011; GFC, 2002). As in many other tropical countries, Guyana's timber industry relies on natural regeneration (Hammond et al., 1996; van der Hout, 1999), meaning that logging that has a detrimental impact on the natural regeneration of commercially important tree species will not be sustainable in the long-term. Historically, the timber industry in the country has centred on *Chlorocardium rodiei* (greenheart), but increased market demand has seen the number of species targeted by logging expand considerably in recent decades (Jonkers, 2002).

Presently, there is a paucity of research into the effects of RIL on natural seedling regeneration within the neotropics (Lobo et al., 2007; Rose, 2000), with the majority of studies focusing on the application of silviculture (Dekker and de Graaf, 2003; Forget et al., 2001; ter Steege et al., 1994), other forms of logging (Kuusipalo et al., 1996; Pinard et al., 1996), or seedling regeneration in the absence of logging disturbance (Baraloto and Goldberg, 2004; Baraloto et al., 2005). Consequently, this paper fills an important gap in our understanding, thus contributing to the improvement of management practices within RIL forest stands and the long-term sustainable use of commercially important target species across their range (Arets, 2005; Putz et al., 2000; van der Hout, 2000).

2. Material and methods

2.1. Study area

Iwokrama forest is located in central Guyana (Fig. 1), covering an area of 371,000 ha^{-1}. It was established in 1996 as a demonstration site to exemplify how tropical forest exploitation can be sustainable, with commercially viable logging being balanced with biodiversity conservation and local community needs (Watkins, 2005). The climate is tropical, with an annual rainfall ~3700 mm across two rainy seasons (May–August and December–January).

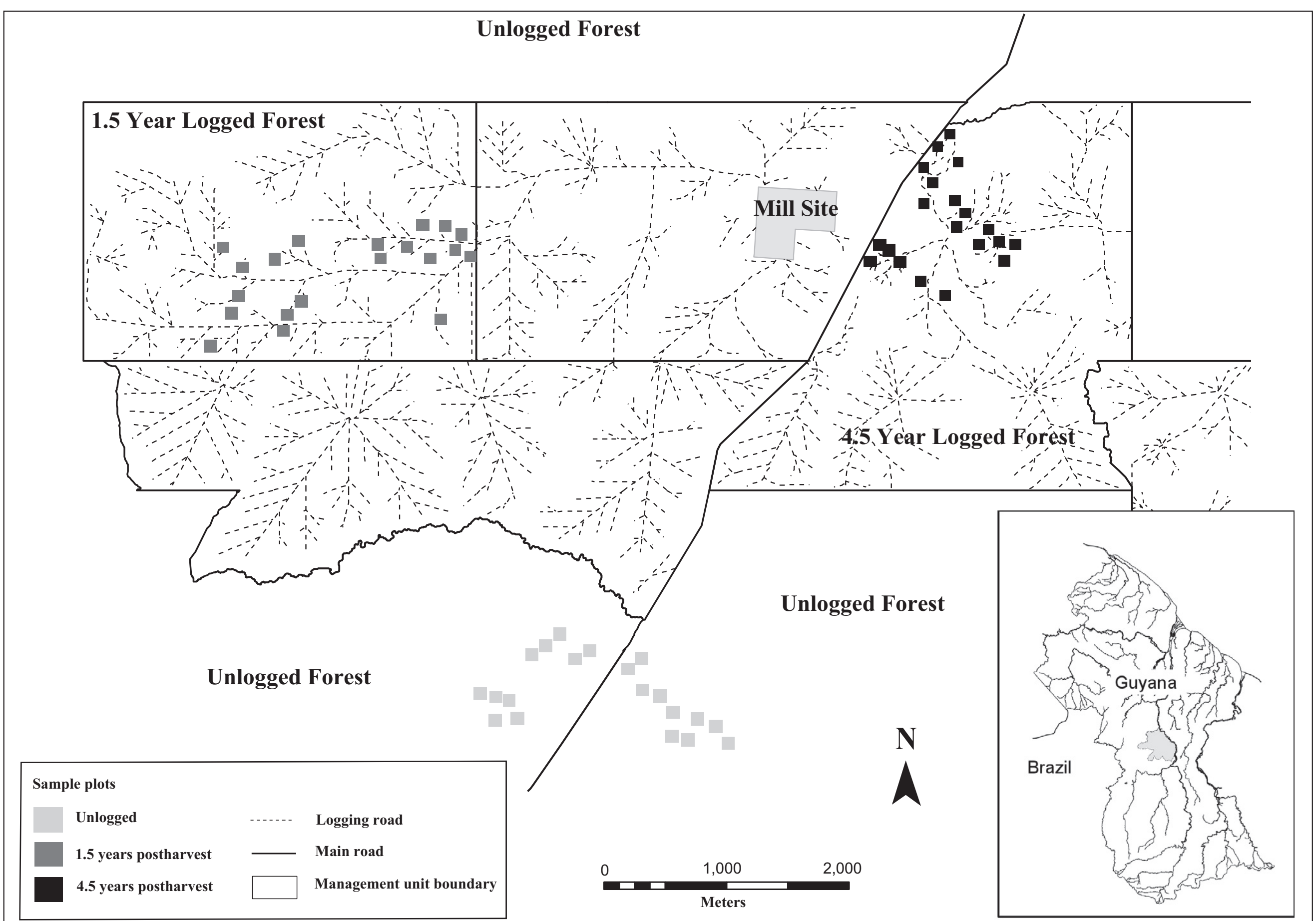

Fig. 1. The location of the study area in Iwokrama forest, Guyana, South America. The Reduced-Impact Logging 1.5 and 4.5 year postharvest treatment plots are indicated by dark grey and black squares respectively. Unlogged forest plots are shown as light grey squares. Logging roads and skid trails (dashed lines) are shown within logged forest to indicate the level of logging disturbance. Inset: The location of Iwokrama forest (shaded grey) within Guyana.