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Thinning of loblolly pine plantations in subtropical Argentina: Impact on microclimate and understory vegetation ☆

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ABSTRACT

During the last three decades, the area dedicated to tree plantations in northeast of Argentina has increased five-fold at the expense of the native semideciduous Atlantic Forest. Silvicultural practices such as thinning affect the understory and forest floor incrementing vegetation cover and diversity that may impact ecological functions such as carbon and nutrient cycling and provide food and shelter for wildlife. The aim of this study was to assess the effects of two thinning intensities (50% and 30% of individual removal), and litter removal in the 50% thinning treatment on the understory vegetation of loblolly pine (*Pinus taeda* L.). The high thinning intensity and the control without thinning were intended to recreate existing management practices in the region. The study was carried out in three *Pinus taeda* plantations (replicates). Environmental conditions and cover of native understory vegetation were measured during two years after thinning. Canopy openness, solar radiation, air temperature and soil bulk density were higher in thinning treatments than in control plots while soil water content was lower. Vegetation cover and richness increased with intensity of the thinning treatments. Tree saplings differed in the responses according to light requirements and height. Light-demanding species and individuals taller than 0.5 m were responsive to thinning increasing coverage, abundance and height, while smaller saplings were more abundant in control plots. No effects of litter removal were observed in understory species richness and plant cover. This study provides evidence that thinning on pine plantations in Northeastern Argentina can contribute in maintaining biodiversity and related ecosystem functions of subtropical forests. Management practices involving lower plantation densities and fewer interventions should be developed to achieve more positive effects.

1. Introduction

Species loss and simplification of ecosystem function and structure have become a major concern worldwide. Despite the goals proposed in the 2010 Convention on Biological Diversity, replacement, fragmentation and degradation of natural areas are still increasing (Secretariat of the Convention on Biological Diversity, 2014). Thus, sustainable management practices that foster biodiversity are needed (Brunet et al., 2000; Gilliam, 2007; Odion and Sarr, 2007; Roberts and Gilliam, 1995). Forest plantations offer an opportunity to maintain biodiversity if sustainable practices are implemented (Carle and Holmgren, 2008).

Silvicultural practices that increase forest understory vegetation may assist in conserving plant species populations. Understory vegetation provides food and shelter for animal species (Dracup et al., 2015; Luck and Korodaj, 2008; Seiwa et al., 2012; Taki et al., 2010; Thompson et al., 2003; Verschuyl et al., 2011), and maintains soil physico-chemical properties and biological activity (Baba et al., 2011; Fu et al., 2015). Understory vegetation contributes little to stand biomass and carbon stores (Ares et al., 2007; Gonzalez et al., 2013), but can enhance carbon and nutrient cycling because of high turnover rates and litter production (Elliott et al., 2015; Poirier et al., 2016).

Silvicultural practices such as thinning have direct and indirect effects on the understory and forest floor. The response of ground vegetation depends on changes in the environmental conditions and available resources, the species composition before thinning,

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and reproductive and functional traits of plants that allow them to colonize the understory (Ares et al., 2009; Bartemucci et al., 2006; Wilson et al., 2009). The increment of resources availability after thinning is in general associated with increasing plant biomass and vegetation cover (Muir et al., 2002; Thomas et al., 1999). Plant species richness may increase during the rotation period because of the continuous establishment of species (Gilliam and Roberts, 2003; Muir et al., 2002; Thomas et al., 1999). However, increased radiation after intense basal area reductions during thinning may increase the abundance of species typical of disturbed environments (Reich et al., 2012; West and Osier, 1995; Wilson and Puettmann, 2007), some of which can be very aggressive competitors (Franklin et al., 2002; Gray, 2005). Resprouting ability typical of some life forms may enhance understory colonization by a few species decreasing richness (Kruger and Midgley, 2001).

The Atlantic Forest of South America is considered one of the eight most important biodiversity 'hotspots' in the world (Myers et al., 2000). This ecoregion extends along the Atlantic coast of Brazil and penetrates into southeastern Paraguay and Argentina. The subtropical forests in northeastern (NE) Argentina are the southern portion of the Atlantic Forest. About 93% of the original forest has been lost due to human activities. Only small fragments of the subtropical semideciduous Atlantic Forest remain in Brazil and Paraguay (Galindo-Leal and Câmara, 2003), while the largest remnants are in Argentina. During the last three decades, the area dedicated to tree plantations in Argentina has increased five-fold (Izquierdo et al., 2008), reaching 1,181,130 ha nowadays (MA, 2016). Large portions of the subtropical forests have been replaced recently by high-yield tree plantations of loblolly pine (*Pinus taeda* L.).

We studied the effect of two thinning intensities and pine litter removal on understory species richness, structure and function under pine plantations in Northeastern Argentina. Particularly, we assessed the effects of thinning on: (1) canopy openness, air temperature, soil bulk density and soil water content, (2) understory vegetation cover and species richness, (3) the composition and abundance of different life-forms, and (4) establishment and growth of tree seedlings with different light requirements. We replicated a thinning experiment in three forest stands. One of the treatments applied corresponded to severe thinning (50%) normally carried out in stands for saw timber harvesting, while the control treatment (no thinning) simulated stands planted for pulp production. We also carried out a moderate thinning (30%) in which we expected to promote vegetation development as in 50% thinning while enhancing species richness by reducing the rapid colonization and dominance of the understory by fast growing invasive species. Low vegetation cover and species richness was expected in control plots. An experiment consisting in a litter removal treatment combined with severe thinning was also carried out in the three stands to assess if needle accumulation on the forest floor was limiting tree regeneration.

2. Materials and methods

2.1. Study area

The study was carried out in three pine plantations (*Pinus taeda* L.) and in adjacent subtropical native forests in Misiones, Northern Argentina. Mean annual rainfall in the area is about 2000 mm and is evenly distributed throughout the year. Mean annual temperature is 21 °C, and frost seldom occurs in winter. The soils, which are derived from basaltic rocks containing high concentration of Fe, Al and Si, correspond to the 9a soil complex (Ligier et al., 1990) that includes Alfisols, Molisols and Inceptisols (Soil Survey Staff, 1992).

2.2. Experimental design

The experiment sites were Palmital 16 (P16, 26°09′59″S 54°26′27″W), Palmital 17 (P17, 26°09′43″S 54°26′35″W) and Campo San Juan (SJ, 26°05′40″S 54°26′48″W) located between 1 km and 5 km apart from each other. All the pine plantations were established in 2006, with an initial density of 1667 individuals per hectare, and were located next to native forest strips (NF). Pine plantations replicates had the same forest management but differed slightly in land use history. The Pamital 16 site has previously had a 38-year old pine forest that was cut down and remained abandoned during four years until the planting in 2006. The Palmital 17 site before the current plantation was occupied by a 35-year old pine forest with a very low density (150 individuals per ha) which allowed the development of a profuse understory. The Campo San Juan site was a disturbed native forest subjected to selective logging. The last two plantations were clear cut in 2006 and immediately planted. The usual management of pine stands in Misiones involves three successive thinning at ages seven, eleven or twelve and fifteen approximately, and a rotation cycle of about eighteen years. Thinning is often carried out by removing the seventh row of pines (hauling roads) every 20 m and then cutting remnant trees until reaching the desired percentage (generally 50%). In this study thinning effects were studied between the first and the second cut (from years seven to ten after planting).

A randomized complete block designed was used in the study. Three 65 × 65 m plots were installed within each pine plantation and thinning treatments were randomly assigned in each block: (1) control (without thinning), (2) T30 (removal of 30% of the pine individuals), (3) T50 (removal of 50% of the pine individuals). A fourth 65 × 45 m plot with 50% thinning was installed in each stand to test the effect of litter accumulation on plant regeneration. In these plots the litter layer was removed (5.6 ± 0.82 cm in depth). The effect of this treatment (T50 + R) on vegetation was compared to the results obtained in T50 treatment. Inside each plot, nine and six (in T50 and T50 + R, respectively) 15 × 15 m subplots were installed for microclimate and vegetation measurements, avoiding hauling roads.

2.3. Stand structure

Total height (H) and diameter at breast height (dbh) were measured in 102 and 130 pine individuals per plot, respectively, before thinning. Plots did not differ in H (13.1 ± 0.08 m) and dbh (0.17 ± 0.001 m) average of pine trees before thinning. Pine density and basal area (BA) did not differ among treatment plots, however, mean tree density in T50 was slightly lower and mean dbh was slightly higher than the other treatment plots (Table 1). Band dendrometers were installed in 36 randomly selected individuals per plot after thinning to measure increment in dbh and monitor changes on stand basal area throughout the duration of the experiment.

Stand structure of the strips of NF remnants next to the plantations was also characterized in order to describe the condition of these forests as potential propagule sources for each stand and thus helped to explaining diverse results among replicates. Plots were installed next to those strips because the distance to native forest is a key factor explaining seed rain and thus potential regeneration (Vespa et al., 2014). All trees ⩾10 cm dbh were measured and species determined in three 10 × 100 m plots in each block; also tree regeneration, vines basal area (Gerwing et al., 2006; Schnitzer et al., 2008) and bamboo cover, were estimated. Strips differed in BA, tree species richness and bamboo abundance, being the SJ and P16 sites the least and most disturbed strips according to these parameters (Table S1). Bamboo abundance is usually high in