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Lack of evidence of edge age and additive edge effects on carbon stocks in a tropical forest

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ABSTRACT

Despite the importance of tropical forest fragmentation on carbon balance, most of our knowledge comes from few sites in the Amazon and disregard long-term underlying processes related to landscape configuration. Accurate estimation of fragmentation effects should account for additive edge effects and edge age. Here we investigated those effects on C stock and forest structure (density, height, basal area) in fragments (13 to 362 ha) of forest with ≥ 70 years old, surrounded by pasture, in the Brazilian Atlantic forest region. We measured 5297 stems sampled in four categories replicated in eight fragments: fragment interiors (> 110 m from edges); old (> 50 years) corner edges (< 50 m); old straight edges; and new (ca. 44 years) straight edges. Aboveground biomass was estimated from tree height and diameter at breast height, and converted to carbon. Carbon stock was highly variable between categories, scoring from 10.44 Mg ha^{-1} up to 107.59 Mg ha^{-1} (average of 41.27 ± 23 Mg ha^{-1}). Contrary to our expectations, interior plots did not have higher carbon stock, basal area or tree stem density than edges, but only taller trees. We found no significant effects of edge age or additive edge effects on carbon stocks. These results suggest that edge effects in the Atlantic rainforest may differ from those observed in more recently fragmented tropical forests, such as the Amazonian forest. We hypothesize that in heavily human-modified landscapes, more extensive edge effects combined with other human disturbances on tree mortality and carbon stock may contribute to overall high levels of degradation, reducing differences between edge and interior habitats. Existing models based on Amazonian forest data may underestimate the true impacts of fragmentation on carbon storage in landscapes with an old history of human disturbance.

1. Introduction

Forest fragmentation *per se* (i.e. breaking apart) of remaining forests is a process related with deforestation, resulting in smaller and more isolated forest patches (Fahrig, 2003), and also in the creation of degraded forest edge areas (Villard and Metzger, 2014). The harsh environmental conditions from the human dominated matrix (e.g. pasture and agriculture areas) surrounding forest fragments (Laurance et al., 2011) affect forest edge habitats, altering microclimatic conditions (Ewers and Banks-Leite, 2013) and biological composition, particularly within the first 100 m (Laurance et al., 2011; Santos et al., 2008; Tabarelli et al., 2008). Tree mortality is one of the most important biological consequences of edge effects (Laurance et al., 1998), particularly for large trees, which are disproportionately susceptible to wind turbulence and physiologic stresses (D'angelo et al., 2004; Laurance et al., 2000; Lindenmayer et al., 2012; Metzger, 2000). The decline in abundance of large trees favors vegetation with lower wood density, including early succession pioneer species and lianas (Laurance, 2002; Laurance et al., 2006, 2001; Poorter et al., 2006; Santos et al., 2008; Tabarelli et al., 2008). Consequently, edge effects may decrease forest aboveground biomass and carbon (C) stock. Recent estimations suggest that degradation at forest edges can be responsible for 9–24% of the total annual C loss associated with tropical forest deforestation (Putz et al., 2014), contributing thus significantly to global climate change, and consequently to biodiversity and ecosystem service loss (IPCC, 2014; MEA, 2005).

Fragmentation and deforestation can affect not only the amount of edge areas, but also their spatial configuration and age. In fragmented

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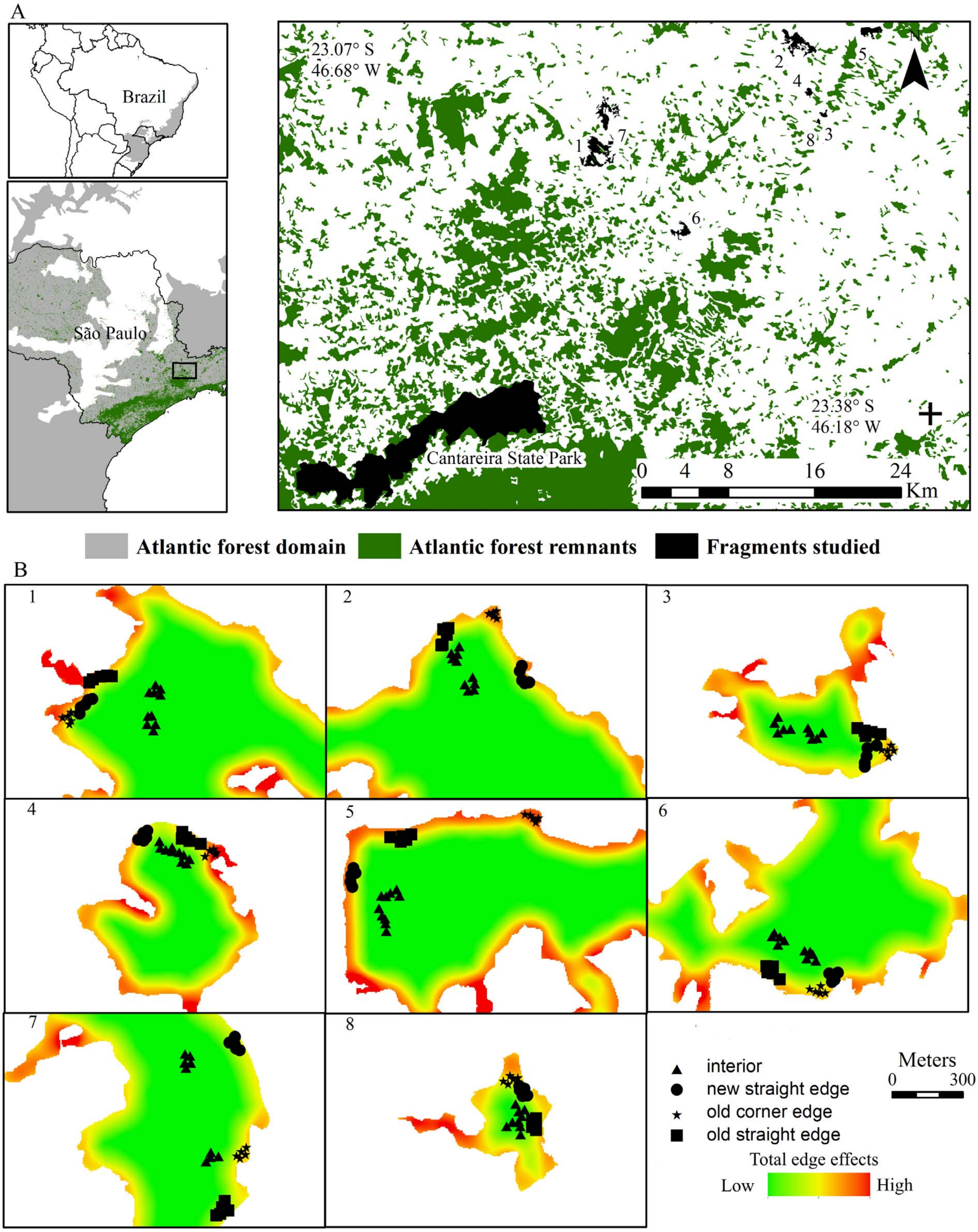

Fig. 1. (A) Location of studied fragments (NE São Paulo state). Light gray shade is the Atlantic forest domain; green are remnant forest patches; black shades are the studied fragments; (B) Plot location in the eight selected fragments. All fragments are represented in the same spatial scale. Each black symbol (triangles, circle, etc.) represents a 10 m radius plot, located in different site categories (see legend). Each site is composed of five plots. We have inventoried 25 plots in each fragment. The color gradient represents the total edge effect index (EI).

landscapes, many forest areas are close to two or more edges (Ries et al., 2004), and thus considering only the closest edge as source of ecological alterations would be an oversimplification. The combined effect of two or more adjacent edges on forest structure and dynamics is termed “additive edge effects” (Malcolm, 1994). Indeed, quantitative meta-analysis (Porensky and Young, 2013) showed that additive edge effects can boost the magnitude of ecological processes occurring at edges (Fletcher, 2005; Laurance et al., 2007; Ries et al., 2004; Zheng and Chen, 2000). As a consequence, the spatial configuration of forest edges due to different patch geometries may also drive forest C stock . We need thus to move forward the current paradigm of considering only the nearest edge in order to consider the influence of additive edge