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Property-level assessment of change in forest clearing patterns: The need for tailoring policy in the Amazon

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ABSTRACT

Once driven by large-scale clearings, Amazon deforestation now occurs mostly in small increments. Did this result from the emergence of a new group of agents or from a strategic adaptation in the behavior of those who led deforestation in the past? We address this question using georeferenced data on private rural properties and deforestation. We cross property-level and forest clearing data in an empirical setting designed to detect shifts toward clearing patches that were knowingly invisible to the monitoring system. We are therefore able to assess not only whether deforesters were responding strategically to stricter monitoring of deforestation, but also how this response differed across actor types. Results suggest that centralized policy efforts introduced starting in the mid-2000s inhibited medium- and large-scale deforestation, but had heterogeneous effects on small-scale deforestation. Although the relative participation of small deforestation polygons increased in both sample states, the relative participation of smallholders in total state deforestation increased in Pará, while remaining constant in Mato Grosso. We interpret these results as suggestive — albeit not causal — evidence that landholders strategically responded to the monitoring system by adapting their forest clearings practices to elude monitoring in both Mato Grosso and Pará. In the latter, however, the increase in smallholders' share of annual deforestation suggests that their clearing practices were relatively less affected by what effectively contained deforestation in large properties. The apparent similarity in scale of deforestation across states conceals relevant baseline differences between the agents engaging in forest clearing in each locality. Tailoring policy to account for such differences could strengthen Brazilian conservation policy.

1. Introduction

Rapid rates of tropical forest clearing observed over recent decades have pushed combating deforestation to the top of the global policy agenda, not least because these forests play a fundamental role in conserving biodiversity, ensuring water quality, and stocking carbon (Stern, 2008; Burgess et al., 2012). Emissions from the forestry sector account for a substantial share of global greenhouse gas emissions: deforestation and biomass decay, in large part originating from the clearing of tropical forests, contributed nearly 20% of total worldwide greenhouse gas emissions in the early and mid-2000s (IPCC, 2007). Brazil plays an important part in this story. Home to nearly two thirds of the Amazon Forest, the planet's largest standing tropical forest tract, the Brazilian Amazon originally covered over 400 million hectares — an area equivalent to about half of continental Europe. Almost a fifth of it has already been cut down (INPE, 2013c). In the first half of the 2000s, Brazil stood out as the country that cleared most tropical forest in both absolute (area) and relative (as share of year-2000 forest cover) terms (Hansen et al., 2008). In 2004, forest conversion and land use change accounted for an estimated 75% of Brazil's total annual emissions (MCT, 2010).

Yet, despite its history of deforestation, Brazil's recent efforts to combat tropical forest clearings are widely regarded as successful. After peaking at 2.7 million hectares per year in 2004, Brazilian Amazon deforestation rates fell sharply in the second half of the decade to about 600 thousand hectares in the early 2010s (INPE, 2013b). Recent works have found evidence that support a significant contribution of public policy to this deforestation slowdown. Assunção et al. (2015) estimate that the reduction in deforestation was partly driven by falling agricultural prices, but that a novel conservation action plan implemented in the mid-2000s also contributed to curb clearing rates. Spatial displacement along one of the Amazon's most active deforestation hot spots has also been shown to have been decoupled from soybean production and cattle ranching processes in the post-policy period

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(Gollnow and Lakes, 2014). In addition to discussing policy impacts, Nepstad et al. (2014) argue that interventions in agricultural commodity supply chains played a relevant role in containing deforestation. Different policy efforts adopted during the slowdown have been assessed individually. Evidence suggests that key contributors were stricter law enforcement — including the adoption of near-real-time satellite monitoring of forest clearing activity and the creation of a municipality-level deforestation blacklist (Hargrave and Kis-Katos, 2013; Assunção and Rocha, 2014; Arima et al., 2014; Assunção et al., 2017) — and conditioning of rural credit concession to compliance with environmental regulation (Assunção et al., 2016).[1]

The Brazilian Amazon deforestation slowdown was not, however, just a change in the absolute level of deforestation — it appears to have been accompanied by a change in the composition of forest clearings. Once driven by large clearings (greater than 25 ha), Amazon deforestation now occurs mostly in small increments. Fig. 1 illustrates this phenomenon. Less than a quarter of total area deforested in the early 2000s was cleared in small patches (defined as contiguous clearings smaller than 25 ha); by the late 2000s, small patches amounted to more than half of annual deforestation. Rosa et al. (2012) have already documented this pattern using a small-patch cutoff area of 50 ha. Yet, the phenomenon becomes more striking — and arguably more policy-relevant — in light of the fact that, in the mid-2000s, Brazil adopted a novel satellite-based Amazon monitoring system that could only detect tropical clearings greater than 25 ha. The system's technical limitation was public information, and could therefore be used as the basis for strategic behavior adaptation by deforesters. Hence our preference for using a 25 ha cutoff for small deforestation patches — in our work, a small deforestation patch is equivalent to one that is not detected by the Amazon deforestation monitoring system. Our study therefore aims at exploring the nature of the change in deforestation composition within the context of stricter, but knowingly limited, environmental law enforcement capacity. Did the increase in the share of small-scale deforestation result from the emergence of a new group of forest clearing agents or from a strategic adaptation in the behavior of those who already led deforestation in the past? We address this topic using georeferenced property-level and deforestation data within an empirical setting fit to identify actor-specific forest clearings that were invisible to the monitoring system.

2. Literature review

The literature has long explored how Amazon forest clearings are distributed across different actors, who are usually classified according to their size (typically into small, medium, large, and very large rural landholdings). Empirical evidence points toward a positive correlation between land concentration and tropical deforestation (de Souza et al., 2013), with medium and large landholdings historically accounting for the majority of cleared Amazon forest area (Walker et al., 2000; Michalski et al., 2010; Pacheco, 2012; Godar et al., 2012, 2014; L'Roe et al., 2016; Richards and VanWey, 2016). Yet, smallholders seem to answer for a disproportionate share — in terms of their own area — of total deforestation. Early estimates attribute about a third of deforestation to smallholders (Fearnside, 1993), a figure which was later corroborated in both Amazon-wide and localized studies (Walker et al., 2000; Pacheco, 2009). However, a consensus is yet to be reached regarding relative actor contributions, with more recent assessments indicating that smallholders may have played a smaller part in Amazon clearings (Godar et al., 2012, 2014; Richards and VanWey, 2016).

Understanding actor-specific roles in Amazon deforestation has not been limited to estimating relative contributions in clearing activity. There is an ongoing effort in the literature to identify behavioral differences across forest clearing agents. Several studies have indicated that smallholders tend to deforest a relatively greater share of their land and to practice a more spatially diffuse pattern of forest clearings (Michalski et al., 2010; Godar et al., 2012; Pacheco, 2012). D'Antona et al. (2006) provide evidence that property size is associated with specific within-property land use patterns in the Amazon even when considering only familial (small) properties. The authors estimate that larger family farms retain a larger share of forest in their landholdings, arguing that this is likely because greater property areas allow room for better management of fallow/regrowth cycles. Godar et al. (2014) have recently complemented these finding, showing that Amazon areas with predominantly small landholdings have proportionally more forest cover and present a lower degree of forest fragmentation and degradation.

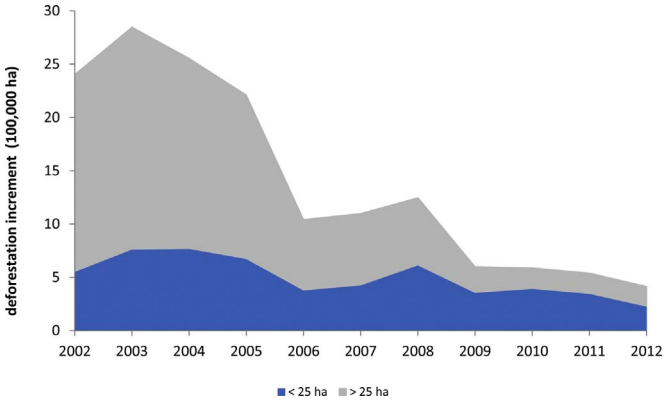

Fig. 1. Amazon deforestation by size of cleared forest patch, 2002–2012. *Notes*: The figure illustrates annual Brazilian Amazon deforestation increment decomposed by size of cleared forest patch.

Despite having made important progress over recent years, empirical assessments of this topic are often limited by the unavailability of Amazon-wide property-level information. Godar et al. (2012) provide a synthetic, yet thorough, overview of the main shortcomings of the literature on actor-specific deforestation in the Brazilian Amazon, including the availability of finer-scale data. Property-level analyses are typically confined to small geographical areas for which there are available data or based on property-level data that have been collected from scratch, but which do not cover the full extent of the Brazilian Amazon, given the very high costs of doing so for such a large area. Examples include D'Antona et al. (2006), who collected on-site and georeferenced data on 126 familial properties, Michalski et al. (2010), who combine both private and official data sets with on-site surveys to build a database of 300 properties, and Godar et al. (2012), who also combine official and original data to yield a sample of more than 8,000 properties. Walker et al. (2000) and Aldrich et al. (2006) cross georeferenced and locally-collected survey data collected in select municipalities along the Transamazon Highway. Although insightful, empirical findings from studies conducted in these areas cannot easily be generalized for the entire Amazon, particularly considering the high degree of actor heterogeneity in the region.

In contrast, works covering the full extent of the Brazilian Amazon resort to municipality or census tract aggregations, classifying each unit of observations according to its predominant property size, as in Pacheco (2009) and Godar et al. (2014). The main limitation with this approach, which does not explore individual property limits, is the inability to determine whether deforestation occurred inside or outside each property, thereby limiting the accuracy of estimates regarding actor-specific contributions. Although we, too, do not have Amazon-wide property-level data, we build on official property-level data to explore the nature of the change in deforestation patch composition

[1] The expansion and strategic location of protected areas in the Brazilian Amazon were also important dimensions of conservation policy adopted during the period of interest, but there is little consensus to date regarding the magnitude of these areas' contribution to the deforestation slowdown. See Nolte et al. (2013), Herrera (2015), and Pfaff et al. (2015) for examples.