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LETTER

Did Ranchers and Slaughterhouses Respond to Zero-Deforestation Agreements in the Brazilian Amazon?

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Abstract

New supply chain interventions offer promise to reduce deforestation from expansion of commercial agriculture, as more multinational companies agree to stop sourcing from farms with recent forest clearing. We analyzed the zero-deforestation cattle agreements signed by major meatpacking companies in the Brazilian Amazon state of Pará using property-level data on beef supply chains. Our panel analysis of daily purchases by slaughterhouses before and after the agreements demonstrates that they now avoid purchasing from properties with deforestation, which was not the case prior to the agreements. Supplying ranchers registered their properties in a public environmental registry nearly 2 years before surrounding non-supplying properties, and 85% of surveyed ranchers indicated that the agreements were the driving force. In addition, supplying properties had significantly reduced deforestation rates following the agreements. Our results demonstrate important changes in the beef supply chain, but the agreements' narrow scope and implementation diminish outcomes for forest conservation.

Introduction

Over the last two decades, the drivers of tropical deforestation have shifted from subsistence agriculture and government resettlement schemes to export-driven commodity agriculture and timber production (Rudel *et al.* 2009; Defries *et al.* 2010). This shift toward more enterprise-driven land use change has accelerated rates of deforestation as vast areas of tropical forests have been converted to croplands and cattle pasture (Achard *et al.* 2002; Gibbs *et al.* 2010; Hansen *et al.* 2013). However, new opportunities for conservation have also emerged, particularly in the beef, soy, and palm oil industries where the commodity traders who process and sell raw agricultural goods and the retailers who buy from them are now more responsive to demands for deforestation-free production (Nepstad *et al.* 2006, 2010, 2014; Butler & Laurance 2008; Dauvergne & Lister 2012; Brannstrom *et al.* 2012; UN 2014; Gibbs *et al.* 2015).

During the last decade, high-profile campaigns by non-governmental organizations (NGOs) have linked deforestation to multinational corporations who buy agricultural goods from forest-rich regions (Greenpeace International 2006, 2009a, 2015). In response, some retailers and commodity traders have imposed environmental criteria on their suppliers. Examples of such supply chain interventions include zero-deforestation agreements and standards issued by international multi-stakeholder commodity roundtables. Interest in supply chain governance is growing rapidly as more countries and companies make high-profile commitments to avoid deforestation (Smith 2008; Walker *et al.* 2013; UN 2014). However, few studies have evaluated the effects of these interventions on the ground, which limits evaluation of

their successes and shortcomings, and opens the door to greenwashing (Rudorff *et al.* 2011; Newton *et al.* 2013; Gibbs *et al.* 2015).

Supply chain governance is particularly relevant in Brazil—a leading global producer and exporter of beef and soy, and home to the world's largest tracts of remaining tropical forest. In response to a combination of government policies, supply chain interventions, and changes in market conditions, Amazon deforestation rates dropped by more than 80% between 2004 and 2014 (Figure S1; Arima *et al.* 2014; Nepstad *et al.* 2014; INPE 2014; Gibbs *et al.* 2015). Even with this decline, Brazil maintains one of the highest absolute rates of deforestation in the world. In 2014, nearly 5000 km^2 were cleared in Brazilian Amazon (INPE 2014). Expansion of cattle pastures continues to be a major cause of deforestation, and pasturelands now occupy at least 60% of cleared land in the Brazilian Amazon (TerraClass 2012).

In 2009, both the Federal Public Prosecutor's Office in Pará state (Ministério Público Federal MPF-Pará) and NGOs pressured the beef and leather retailers and meatpacking companies, which own and operate slaughterhouses, to reduce deforestation associated with cattle production. The MPF-Pará sued ranchers who cleared forest illegally and the slaughterhouses that bought from them, and used threats of litigation to convince Brazilian retailers to boycott slaughterhouses connected to illegal deforestation (Barreto & Silva 2010; Sist *et al.* 2013). In response, individual meatpacking companies in Pará began signing the legally binding Terms of Adjustment of Conduct ("MPF-TAC") agreements in July 2009 to stop purchasing from properties with illegal deforestation (Ministério Público Federal 2009, 2013a, 2013b). These agreements have since been replicated in other Amazonian States—Acre, Rondônia, Amazonas and Mato Grosso—and now include two-thirds of the federally inspected slaughterhouses (SIFs) in the Legal Amazon (Figure 1). In October 2009, Brazil's largest meatpacking companies, Marfrig, Minerva, JBS, and Bertin (the latter was subsequently purchased by JBS), also signed the "G4" zero-deforestation agreement with Greenpeace in response to high-profile campaigning that leveraged pressure from retailers and brands concerned about the reputational risks of being associated with deforestation (Greenpeace International 2009b).

The G4 and MPF-TAC agreements share the same timeframe and basic tenets: meatpacking companies committed to block sales from properties with deforestation occurring after the agreements or that were not registered in the Rural Environmental Registry (Portuguese acronym CAR), which stores georeferenced property boundaries for monitoring purposes. The MPF-TAC agreements emphasize avoiding illegal deforestation as defined by the Brazilian Forest Code, which stipulates that 80% of a property's forest area must be reserved as a set-aside across much of the Brazilian Amazon biome (Ministério Público Federal 2013a, 2013b). The G4 agreement goes farther and prohibits any clearing, even if within the legal limit. Both agreements currently govern only those properties selling directly to slaughterhouses ("supplying properties"), thereby excluding all other indirect supplying properties that cattle are commonly moved between such as calving and breeding ranches (Walker *et al.* 2013). These indirect suppliers are mentioned in both agreements, but implementation efforts have been minimal. Under the G4 agreement, JBS, Marfrig, and Minerva committed to set up monitoring systems to manage deforestation risk in their individual supply chains. They use PRODES deforestation maps produced by the Brazilian Institute for Space Research (INPE) to identify deforestation on their direct supplying properties, which sell half of the cattle slaughtered in the Brazilian Amazon (MAPA 2013). Other companies do not yet have deforestation monitoring systems.

Here, we present the first empirical study of cattle supply chains aiming to quantify meatpacker and rancher response to the zero-deforestation agreements. We considered the four large JBS slaughterhouses in southeastern Pará, which signed both agreements in 2009. These plants account for 30% of slaughter in Pará, and were the only slaughterhouses in the state operating before and after the agreements with deforestation monitoring systems (Figure S2). First, we assessed their response to the requirement that suppliers must be in the CAR registry. Next, we examined whether JBS changed purchasing behavior after the agreements to avoid properties with recent deforestation. Finally, we examined differences between the properties that JBS purchased from before and after the agreements to characterize potential changes in deforestation rates and trends.

Methods

Study area

Pará state has the largest cattle herd within the Brazilian Amazon biome, with 19.2 million head as of 2013, when the state accounted for 20% of beef exports and all live cattle exports from the biome (IBGE 2014; Secex & MDIC 2014). Our study focused on the southeast portion where 70% of Pará's large SIFs are located (Figure S2). This region is dominated by cattle production with <2% of the agricultural area planted to soy in 2014 (Gibbs *et al.* 2015). Pará accounted for 40% of Amazonian deforestation over the last decade, much of which occurred in the

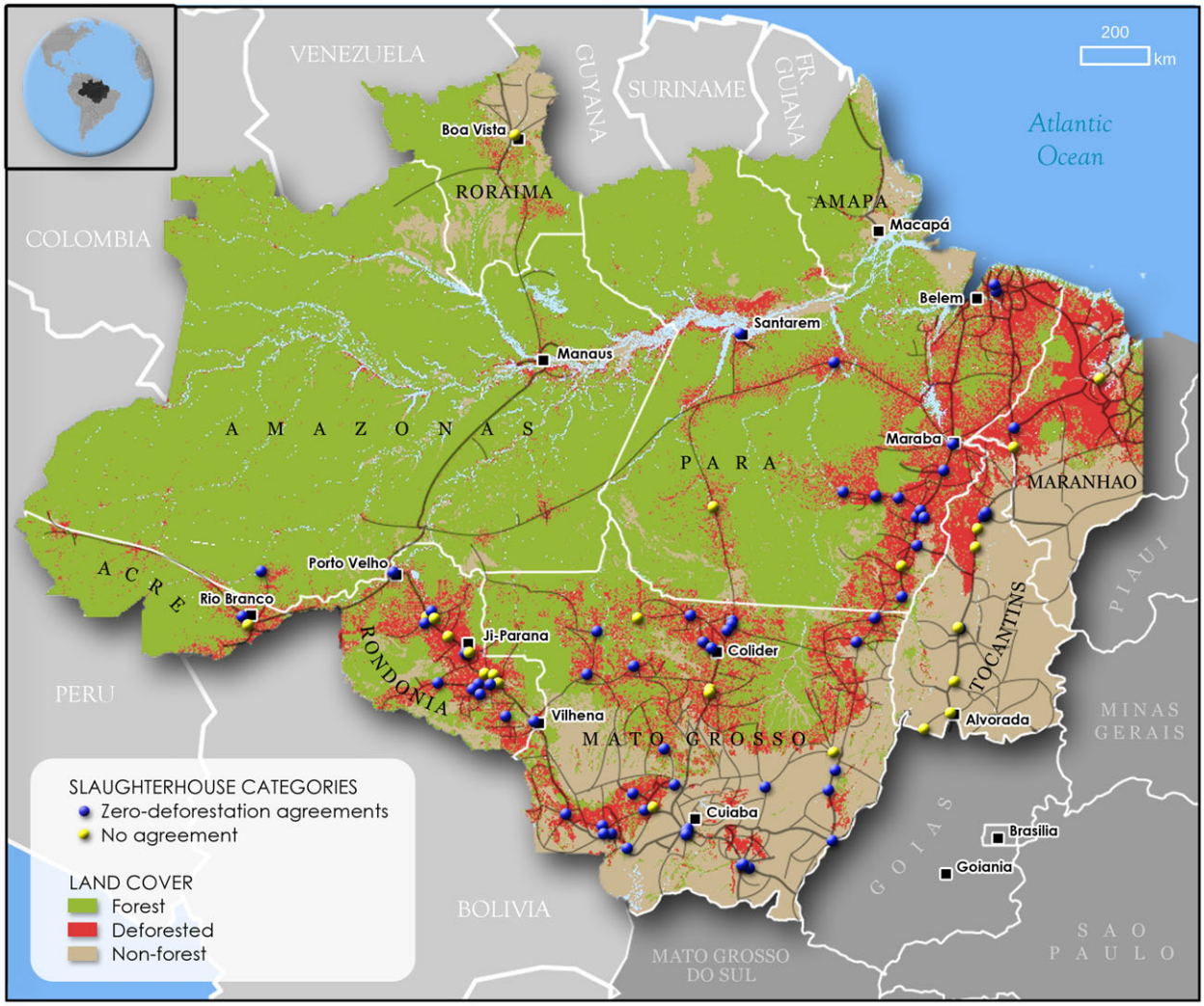

Figure 1 Major slaughterhouses in the Brazilian Legal Amazon that have and have not signed a zero-deforestation cattle agreement (includes both MPF-TAC and G4). Slaughterhouse locations identified using GPS locations collected in the field and high-resolution imagery via Google Earth. Only federally inspected slaughterhouses (SIFs) are depicted. Smaller slaughterhouses are excluded. The Legal Amazon is defined by law to include the states of Acre, Amapa, Amazonas, Para, Rondonia, Roraima, Mato Grosso, Maranhao, and Tocantins, which each contain a portion of the Brazilian Amazon biome.

southeast where almost half of the primary forest was cleared by 2014.

Property-level supply chain mapping

To assess meatpacker and rancher response to the agreements, we first developed a supply chain mapping approach that combines maps of property boundaries with data on cattle purchases. We downloaded daily cattle purchase information for the JBS slaughterhouses, October 2008–December 2013 (JBS 2013). The data included date of purchase, property name, owner name and identification number, and municipality for 54,993 transactions involving ~3,600 properties that sold cattle directly to the slaughterhouses. The type of information available has varied through time. We wrote computer scripts to standardize all input datasets. A matching algorithm was used to link the cattle purchase data to the owner identification number and farm name included in the CAR registry, allowing for slight variants of the same name (SIMLAM 2013). Through this process, we identified the location and boundaries of the supplying properties for 43,526 (79%) of the transactions during the study period. The remaining 21% were either with unregistered properties or with properties that had unresolvable discrepancies in identifying information.

We defined our study area to include all CAR properties within 10 km of a supplying property, which helped to ensure similar infrastructure access and geographic conditions (Figure S3). These non-supplying properties may sell directly to other nearby plants (Figure S2) or sell to other properties, which may sell to JBS slaughterhouses. Similar purchase data is not available from any other slaughterhouses. The final spatial dataset was comprised of 39,794 CAR-registered properties, including the 2,723 supplying properties and the 37,071 non-supplying properties located in the study area. We also applied structured surveys to seven slaughterhouses, 131 ranchers, six syndicates, and 70 key informants in the study region during 2013 and 2014 to better understand the drivers of behavior changes and regional context (SOM 1.3).

CAR property registration

To assess the impacts of the agreements on CAR registration rates, we tracked changes in the portion of slaughterhouse purchases with registered properties (SOM 1.1). We ran *t*-tests with unequal variance and Wilcoxon rank-sum tests to determine if there were significant differences in the mean and median registration dates for post-agreement supplying properties compared with those that supplied only before the agreement, and to surrounding non-supplying properties.

Slaughterhouse purchasing behavior

We quantified the impact of recent deforestation on slaughterhouse purchase probability before and after the zero-deforestation commitments. We used panel data on annual deforestation for supplying and surrounding non-supplying properties (2009–2013) and fit a linear probability model that included property- and year-level fixed effects to consider changes in purchasing behavior (SOM 1.2). These fixed effects controlled for time-invariant characteristics of each parcel such as size, location, and initial forest cover, and for average effects that vary year to year, such as market conditions.

Deforestation and forest cover were estimated using the annual Landsat-based PRODES deforestation maps (INPE 2014). "Recent deforestation" was defined as deforestation ≥6.25 ha, the minimum mapping unit for PRODES, detected in either of the two years prior to purchase. Because of the schedule of PRODES data releases, slaughterhouses have access only to the previous years' deforestation data when making purchasing decisions (not the current year) and we have replicated these conditions in our model (Table S1). This means that a robust response to the agreements is not expected until 2012, when all of the recent deforestation was detectable and occurred after the agreements.

Supplying property characteristics

We assessed changes in the property size, forest cover, location, and deforestation rates of properties selling to the JBS slaughterhouses by comparing three groups: (1) those selling after the agreements in 2013 but not before the agreements ("post-agreement"); (2) those selling only before the agreements in 2009 ("pre-agreement"); (3) and those selling in both 2009 and 2013 ("stable"). To evaluate changes in supplying properties after the agreements, we used difference-in-differences tests to compare mean deforestation rates normalized by forest area during the three years before (2006–2008) and after the agreements (2010–2012) on pre-agreement and post-agreement supplying properties. Properties missing owner identification information or not registered in the CAR were excluded.

Results

CAR property registration increased rapidly

In 2006, new state regulations mandated CAR registration for agricultural properties in Pará (Azevedo *et al.* 2014). Despite the legal requirement, only 2% of purchases were with registered properties when the G4 agreement was signed in October 2009 (Figure 2a). By early 2010 implementation deadline for both agreements, nearly 60% of the slaughterhouses' monthly transactions were with registered suppliers. By the end of 2013, 96% of transactions were with registered properties (Figure 2a).

Properties that supplied after the agreement were registered significantly earlier than both surrounding non-supplying properties and pre-agreement supplying properties (Figure 2b). Of the post-agreement supplying properties, 52% registered within a year of the G4 agreement. Only 16% of non-supplying, surrounding properties registered during this period. Instead, 44% of these non-supplying properties registered more than three years later following increased state government pressure and support, particularly for smallholders. Wilcoxon rank-sum and *t*-test results confirm that post-agreement suppliers registered significantly earlier. The median registration date for these suppliers was 756 days earlier than non-supplying properties and 374 days earlier than pre-agreement supplying properties ($P < 0.001$; Table S2). Of the 56 JBS suppliers we interviewed in southeastern Pará, 85% specified that they registered their properties in order to sell to JBS.

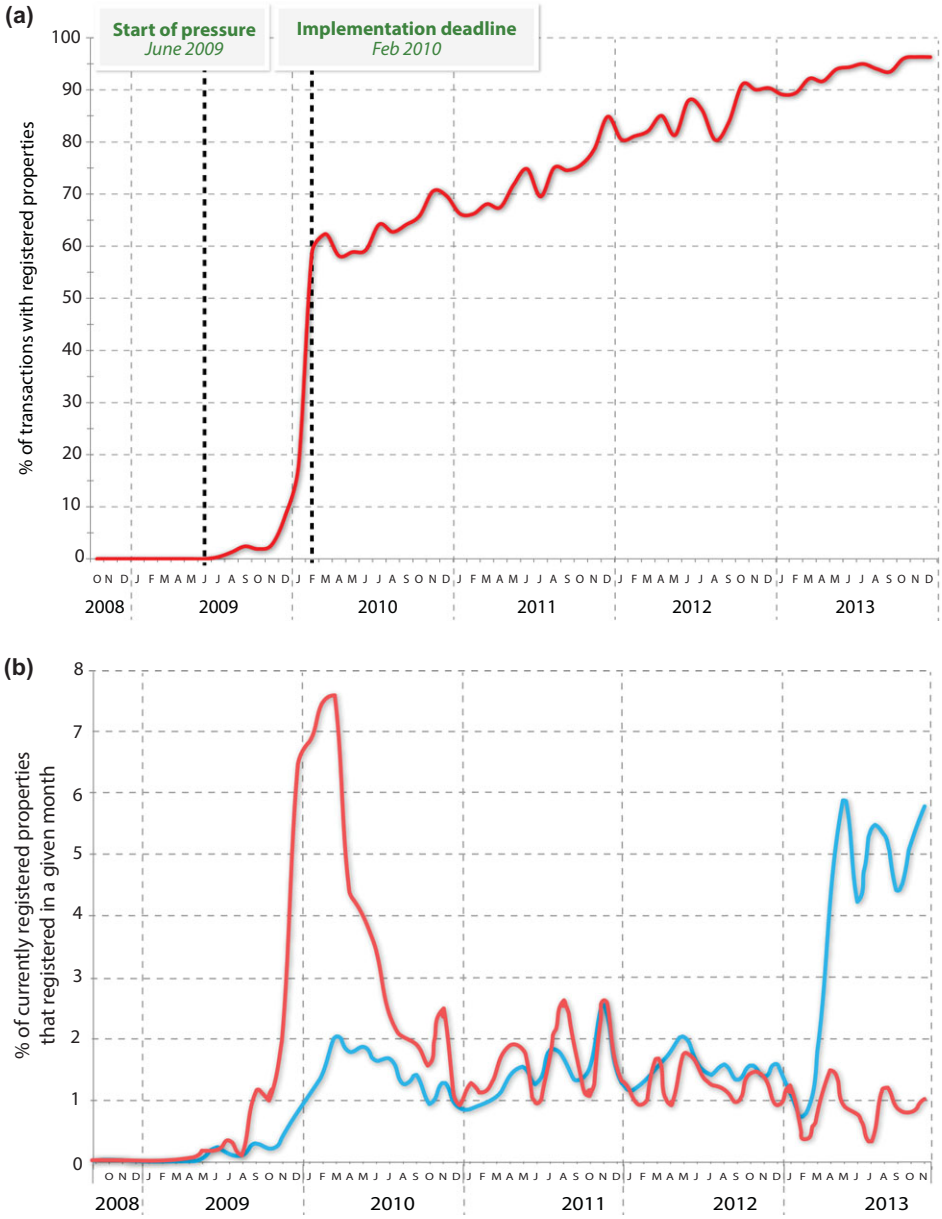

Figure 2 Timing of property registration with the CAR system. (a) The portion of monthly JBS slaughterhouse transactions with registered supplying properties increased dramatically following the zero-deforestation agreements. (b) The JBS slaughterhouses incentivized rapid registration of supplying properties immediately following the agreements (red line). Registration of other properties within 10 km but not selling to a JBS slaughterhouse spiked much later (blue line).

By contrast, only 35% of the 69 non-suppliers indicated that the agreements motivated registration.

Slaughterhouses reduced purchases from recently deforested properties

In 2009, 36% of supplying properties had recent deforestation but this fell to 4% by 2013. Results from the panel analyses demonstrate that the probability that JBS slaughterhouses would purchase from a property was not affected by recent deforestation before the agreement, but that they avoided properties with deforestation after the agreement (Table 1; Table S3; Figure 3). The effect of recent deforestation on purchase probability was almost zero before the agreements among the group of properties that had ever sold to JBS and had remaining forest. By 2013, the purchase probability was cut in half

Table 1 Average effect of recent deforestation on the JBS slaughterhouse purchase probability[a,b]

	Model 1	Model 2	Model 3	Model 4
	Supplying and non-supplying properties located within 10 km	Supplying and non-supplying properties located within 5 km with ≥6.25 ha forest in 2009; excluding INCRA resettlements	Supplying properties	Supplying properties with ≥6.25 ha of forest in 2009
Deforestation effect on 2009 purchases	−10.56	−6.36	1.03	−0.02
Deforestation effect on 2010 purchases	14.33*	11.65	6.64	5.97
Deforestation effect on 2011 purchases	20.59**	9.18	16.59**	10.94*
Deforestation effect on 2012 purchases	−46.05***	−35.03***	−45.18***	−39.96***
Deforestation effect on 2013 purchases	−62.85***	−47.65***	−59.91***	−52.34***
Number of parcels	39,794	14,374	2,723	1,810

[a]Deforestation effect is defined as the percent change in predicted purchase probability if deforestation is detected during the previous two years.
[b]We conducted model runs using a variety of time windows and deforestation thresholds; results are all qualitatively similar and available upon request.
*$P < 0.05$.
**$P < 0.01$.
***$P < 0.001$.

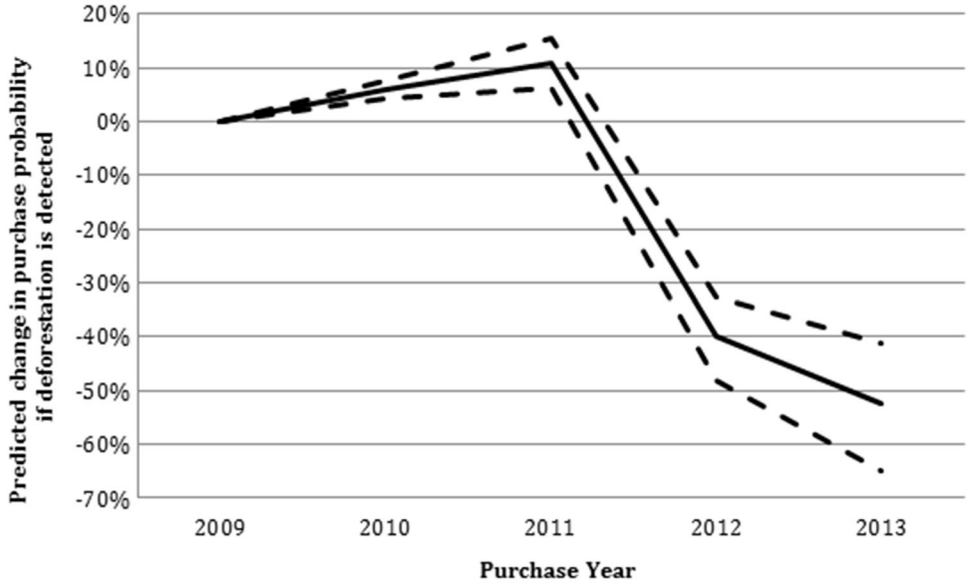

Figure 3 Effect of recent deforestation on slaughterhouse purchase probability. Panel analysis results demonstrate that the JBS slaughterhouses were significantly less likely to purchase from properties with recent deforestation by 2012 ($P < 0.001$). Prior to the agreements, deforestation did not have a statistically significant impact on their purchasing selection. At least some of the deforestation assessed by our models for 2010 and 2011 occurred prior to the agreements; 2012 is the first year we would expect a full response (Table S1). Graphic based on Model 4 sample (Table 1; Table S3).

when recent deforestation was detected on a property (Figure S2; $P < 0.01$). We produced similar results using a range of sample definitions (Table 1; Table S3). Our results provide strong evidence that these slaughterhouses disproportionately favored properties without deforestation in response to the agreements, an effect that goes beyond the overall decline in deforestation rates across the region.

Post-agreement supplying properties had lower deforestation rates

Pre-and post-agreement supplying properties have significantly different characteristics and deforestation trends (Table 2). The mean size of pre-agreement supplying properties (~1,300 ha) was significantly smaller than the post-agreement supplying properties (~1,800 ha), and

Table 2 Comparison of average characteristics for CAR-registered properties that supplied only before the agreement, only after the agreement, or in both 2009 and 2013[a]

	Pre-agreement supplying properties[b]	Post-agreement Supplying properties[c]	Difference between pre- and post-agreement supplying properties	Stable supplying properties that sold pre- and post-agreement[d]
Number of properties (*n*)	499	577	−78	178
Mean distance to nearest study slaughterhouse (km)[e]	100.4 (3.7)	74.7 (2.1)	25.8*** (4.3)	67 (3)
Mean property size (ha)	1270 (135)	1839 (166)	−569** (214)	3158 (435)
Mean forest area at end of 2009 (ha)	378 (53)	527 (79)	−149 (95)	978 (214)
Mean proportion of property forested	0.208 (0.011)	0.152 (0.008)	0.056*** (0.013)	0.193 (0.014)
Number of properties with ≥6.25 ha forest in 2009 (*n* for next three rows)	409	433	−24	156
Mean proportion deforested from 2006 to 2008 (pre-agreement)	0.157 (0.012)	0.193 (0.014)	−0.036* (0.018)	0.153 (0.020)
Mean proportion deforested from 2010 to 2012 (post-agreement)	0.045 (0.007)	0.024 (0.006)	0.020* (0.009)	0.011 (0.006)
Difference-in-difference for deforestation rate before and after agreement agreement			−0.056** (0.021)	

[a]Statistical tests for non-zero differences in means are based on Student-*t* tests, unpaired and with unequal variance; standard errors are in parentheses.
[b]Supplying properties that sold in 2009, prior to the agreements, but did not supply after the agreements and for which we had owner identifying information.
[c]Supplying properties that sold in 2013, after the agreements were implemented, but did not supply before the agreements, and for which we had owner identifying information.
[d]Only properties supplying in both 2009 and 2013 were included.
[e]Distances represent straight-line distances, not road-based distances.
*$P < 0.05$.
**$P < 0.01$.
***$P < 0.001$.

less than half the size of stable suppliers (~3,200 ha). Post-agreement supplying properties also had a significantly lower proportion of remaining forest ($P < 0.001$), with an average of 15% of forest remaining compared with the ~21% found on pre-agreement suppliers. Roughly a third of post-agreement properties had <1% forest remaining, and only 31 properties contained ≥80% forest cover. These more recent supplying properties were also located 26 km closer to the nearest slaughterhouse ($P < 0.001$).

All groups had lower deforestation rates after the agreements (2010–2012) than beforehand (2006–2008). However, post-agreement supplying properties had more significant rate reductions than pre-agreement suppliers ($P < 0.01$), in part because they had higher deforestation rates before the agreements ($P < 0.05$). These newer supplying properties also had significantly lower deforestation rates after the agreement ($P < 0.05$).

Discussion

Our results demonstrate that the supply chain agreements incentivized rapid change in meatpacker and rancher behavior related to deforestation and property registration in the state of Pará. The JBS slaughterhouses we analyzed actively excluded ranches with deforestation from their supply chain, signaling to ranchers that deforestation means reduced market access. They also motivated their suppliers to rapidly register their properties in the CAR system by restricting market access for

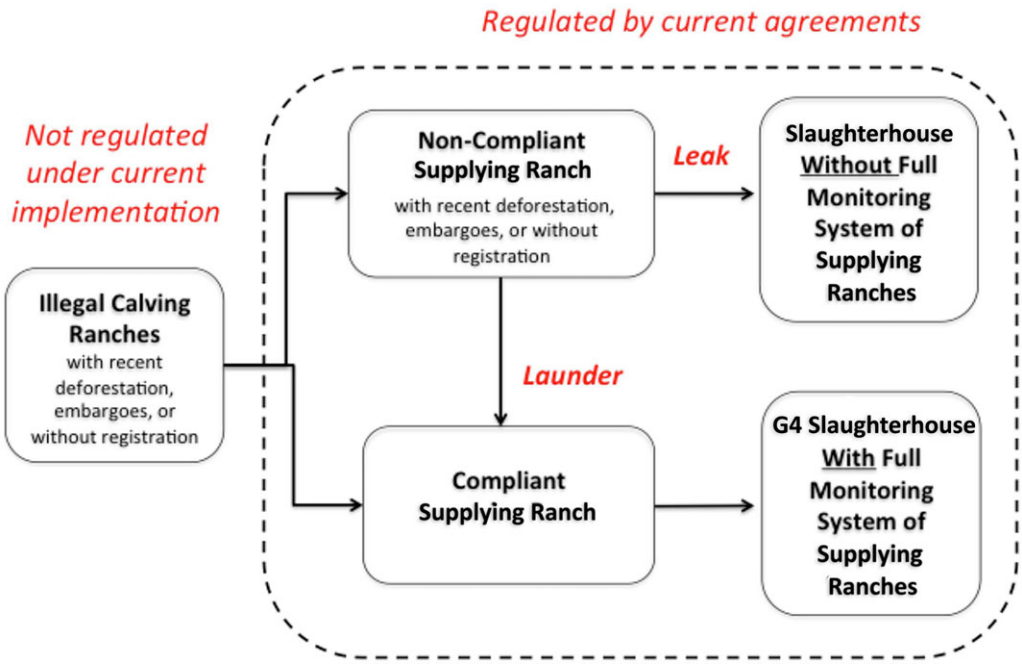

Figure 4 Large portions of the beef supply chain are not yet monitored under the zero-deforestation agreements. In practice, the agreements regulate only direct purchases from supplying farms, thus ignoring calving ranches and other indirect parts of the supply chain. Cattle fattened on noncompliant properties with deforestation can leak to slaughterhouses that lack full monitoring systems; these cattle can also be laundered by moving them to a compliant ranch for direct sale to a slaughterhouse.

unregistered properties, thereby moving ahead previously stalled state government mandates. Nearby non-supplying properties tended to wait at least two additional years to register in response to more localized government support and pressure. Compared with pre-agreement suppliers that did not sell to JBS following the agreements, the rates of deforestation in 2010–2012 were 50% lower on post-agreement supplying properties, and 75% lower on stable properties that sold in both 2009 and 2013 (Table 2). The differences in deforestation trends, combined with the strong rancher response in property registration, indicate that ranchers may have responded to the agreement by reducing deforestation on supplying properties. However, additional work is needed to quantify the degree to which the agreements are responsible for these reductions, and to assess the slaughterhouse and rancher response in other states that may have less pressure to comply with the agreements.

Despite these achievements, the outcomes for forest conservation are limited by the narrow application of the agreements, which opens the door to laundering and leakage (Figure 4). For example, large segments of the cattle supply chain are not monitored or tracked under the current implementation (Walker *et al.* 2013). Cattle often spend time on multiple properties prior to slaughter, and ranchers can raise and fatten cattle on noncompliant ranches without a CAR or with recent deforestation, and then move the animals to a compliant property before sale to the slaughterhouses ("laundering"). Cattle laundering may also happen through "middlemen" who buy cattle from many producers, including those with noncompliant properties, and then sell to slaughterhouses through their own compliant property. During field surveys, ranchers reported that such laundering is a common and accepted practice, and pointed to the fact that it is not prohibited by the agreements. "The cows are not embargoed, only the land" was a common sentiment. Cattle produced on ranches with recent deforestation could also be sold to nearby slaughterhouses that do not have monitoring systems, allowing the deforestation to "leak" into these unregulated supply chains (Figure 4; Figure S2).

Ultimately, tracking individual animals with ear tags or other devices may be necessary to guarantee full supply chain traceability and deforestation-free beef, but this is likely years away from implementation. In the near term, the following refinements of the zero-deforestation agreements could improve forest conservation outcomes: (1) create a universal monitoring system available to and implemented by all meatpacking companies, regardless

of size, which could also be accessed by the retailers who purchase from them; (2) broaden the implementation to encompass the full supply chain, including calving ranches and other indirect supplying properties; (3) provide data to track the full supply chain by publicly releasing the Guide to Animal Transport data (GTA), which tracks movement of cattle between farms for animal health purposes; (4) accelerate CAR registration for all properties, providing additional support for smallholders (Lee *et al.* 2012); and (5) mandate comprehensive, spatially-explicit and independent audits of slaughterhouse compliance (SOM 2).

Notwithstanding the remaining challenges, the experience in Pará demonstrates that simultaneous pressure from NGOs and government bodies can be a potent way to change rancher and slaughterhouse behavior, and reduce the amount of deforestation entering the beef supply chain from direct supplying properties. Slaughterhouses are a key leverage point in the supply chain due to their physical location in the agricultural-forest frontier, daily interactions with ranchers, and ability to restrict market access immediately. Committed corporations could improve the environmental performance of the agribusiness supply chains in areas where remoteness makes direct law enforcement difficult or less cost effective. These targeted supply chain interventions can produce results in a period of months rather than years, which has been typical of multinational agreements such as REDD+ and national policies such as the Forest Code (Gibbs *et al.* 2015). However, achieving large-scale reductions in deforestation will depend on scaling these agreements to include the majority of slaughterhouses and the entire supply chain, including indirect suppliers. Expanding these interventions beyond Brazil would require investments in supply chain traceability and transparency, but the monitoring technology is within reach.

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Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's web site:

Table S1. Dates of PRODES deforestation years defined as recent deforestation in panel analysis on the effect of supplying property deforestation on JBS slaughterhouse purchase probability.

Table S2. Results of t-tests and Wilcoxon rank-sum comparing CAR registration dates between post-agreement supplying properties and both surrounding non-supplying properties and those that supplied only before the agreements.

Table S3 Results of linear probability models with property-and time-level fixed effects assessing the impact of recent deforestation on slaughterhouse purchase probability.

Figure S1. Cattle production and deforestation trends in the Brazilian Amazon biome, 1990-2014 (PRODES 2014, IBGE 2014).

Figure S2. Location of study region in southeastern Pará state. Only federally inspected slaughterhouses (SIFs) are depicted. Smaller slaughterhouses are excluded.

Figure S3. Example of property boundaries from the CAR database for supplying ranches and surround non-supplying properties.

Figure S4. The effect of recent deforestation on slaughterhouse purchase probability. Panel analysis results demonstrate that the JBS slaughterhouses were significantly less likely to purchase from properties with recent deforestation by 2012 ($p < 0.001$). Prior to the agreements, deforestation had no statistically significant impact on their purchasing selection. At least some of the deforestation assessed by our models for 2010 and 2011 occurred prior to the agreements; 2012 is the first year we would expect a full response. Graphic based on Model 4 sample and provides another way to visualize results in Figure 3 (Table 1; Table S3)

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