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LETTER

Protected areas still used to produce Brazil's cattle

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Abstract

Cattle production inside Brazil's protected areas (PAs), including indigenous lands, continues to contaminate Amazonian supply chains more than a decade after efforts to reform the sector were launched with the signing of the zero-deforestation cattle agreements (CAs). During 2013–2018, nearly 1.1 million cattle head were sold directly from private properties inside PAs to slaughterhouses in Mato Grosso, Pará, and Rondônia states. Another 2.2 million head were linked via indirect suppliers located in PAs. Most of these 3.3 million slaughtered head were originated in to sustainable-use areas (72%), where cattle ranching may be permitted in certain cases; however, production also occurred in strictly protected units (20%) and indigenous lands (8%), where commercial grazing activities are illegal and prohibited by the CAs. Nearly half of the PA properties linked to cattle transactions from 2013 to 2018 also had deforestation. We estimate that approximately 2.8 million cattle head from properties in PAs were sold to slaughterhouses participating in the CAs (86% of the total cattle from indirect suppliers in PAs). Controlling commercial cattle production inside of PAs is crucial to both ensure Brazil's access to international beef markets and protect critical biodiversity regions in the Amazon rainforest.

KEYWORDS
Amazon, deforestation, grazing, pasture, supply chain, tropical forest

1 | INTRODUCTION

After a period of decline in forest loss in the Brazilian Amazon between 2004 and 2012, deforestation is again on the rise (West & Fearnside, 2021). This new trend has accelerated under the current administration, associated with a systematic dismantling of federal environmental regulations (Abessa et al., 2019; Tollefson, 2018). Between 2018 and 2020, deforestation rates increased by 47%, with nearly three-fourths of the loss concentrated in Mato Grosso,

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Pará, and Rondônia states (INPE, 2021). While protected areas (PAs), including indigenous lands (ILs), have historically contributed to conservation in the region (Blackman & Veit, 2018; Jusys, 2018; Nolte et al., 2013; Pfaff et al., 2015; Soares-Filho et al., 2010), they are still exposed to illegal land-use activities leading to forest loss and fragmentation, often associated with cattle ranching (Cabral et al., 2018; Klingler et al., 2018; Kröger, 2020). This ongoing process can also ultimately lead to PA downgrading, downsizing, or degazettement (Keles et al., 2020). Given the rollbacks in Brazil's environmental policies, reducing pressure on PAs through effective monitoring of cattle supply chains and slaughterhouses' zero-deforestation commitments is key for rainforest conservation (Lambin et al., 2018; Nepstad et al., 2014).

Historically, ~80% of Amazonian deforestation resulted from pasture expansion (Barona et al., 2010; Tyukavina et al., 2017). In response to NGO-led campaigns linking beef production to environmental degradation and to a series of lawsuits against ranchers and meatpackers tied to illegal deforestation led by the Brazilian Federal Public Prosecutor's Office (MPF; Portuguese acronym), two different types of zero-deforestation cattle agreements (CAs) emerged. The first of these CAs were legally binding environmental commitments, known as the cattle sector "TACs" (*Termos de Ajuste de Conduta* in Portuguese; Gibbs et al., 2016). They were first signed in July 2009 between individual meatpacking companies and the MPF and have continued to expand through time. These TACs required slaughterhouses to stop purchasing cattle from farms with illegal deforestation or that were otherwise out of compliance with environmental and labor requirements (Gibbs et al., 2016; Walker et al., 2013). In October of the same year, the four largest meatpacking companies in Brazil (JBS, Bertin, Minerva, and Marfrig) signed an additional CA, the *Public Livestock Agreement* (also known as the "G4"; Greenpeace International, 2009), which limits purchases from properties with any type of deforestation, illegalities, or located in any type of PAs (in addition to other socioenvironmental requirements). With these CAs in place, farms that sell cattle to slaughterhouses can be found noncompliant and excluded from supply chains for violating CA rules.

Since 2009, the MPFs have extended TAC coverage to new slaughterhouses and, in Pará, have begun conducting audits of meatpacker compliance with the TAC with publicly disclosed results. Recently, the MPF and civil society groups published a set of standard monitoring rules for the CAs, known as the "Unified Protocol" (MPF, 2020). These rules also outlined for the first time the potential for excluded suppliers to overturn their violation and become compliant again. For example, an excluded property within a sustainable-use PA (SUPA) with a formally approved management plan for agropastoral activities could legally become a supplier of CA slaughterhouse.

Despite important advances, the enforcement and monitoring of the CAs remains challenging (Klingler et al., 2018; Pereira et al., 2020). To date, nearly 75% of the major slaughterhouses in the Brazilian Amazon have committed to the CAs and most have established monitoring systems. These systems aid slaughterhouses in making purchase decisions by checking supplier information against several databases, including PA and deforestation maps. However, cattle supply chains are complex and multitiered, as cattle may be bred and fattened on multiple farms before reaching the slaughterhouse (Carvalho et al., 2021), and slaughterhouses often struggle to identify their indirect suppliers. As a result, even cattle from slaughterhouses' direct suppliers that are verified deforestation-free could be associated with deforestation on indirect supplier properties (Gibbs et al., 2016). New initiatives that seek to increase accountability for deforestation on indirect suppliers are emerging, though they have yet to be widely adopted (GTFI, 2019; SEMAS, 2021; Visipec, n.d.).

Here, we assess the prevalence of commercial cattle production in PAs using official cattle transaction records across the three most important beef-producing states in the Brazilian Amazon. We tracked sales from properties located in PAs that sell directly to slaughterhouses, as well as indirectly. We analyzed three categories of PAs: SUPAs, strictly protected areas (SPAs), and ILs. Our findings indicate that PAs are a significant source of cattle produced in the Amazon.

2 | METHODS

We compiled three main datasets to identify and track illegal cattle transactions between PAs and slaughterhouses in the states of Mato Grosso, Pará, and Rondônia: (1) cattle transit records from the Brazilian Ministry of Agriculture, Food, and Livestock's Guide to Animal Transport (GTA) database; (2) property boundaries from the Rural Environmental Registry (CAR; Portuguese acronym; self-declared), the National Institute of Colonization and Agrarian Reform (INCRA; Portuguese acronym), and the *Terra Legal* databases; and (3) PA boundaries from the Brazilian Ministry of Environment (MMA; Portuguese acronym) and the National Indian Foundation (FUNAI; Portuguese acronym; Tables S1 and S2). Federal regulations require ranchers to report all cattle transactions in the GTA system (Law 12,097 of 2009 and Decree 7623 of 2011). These records are used to ensure that producers have met animal health standards and are assumed to document most of the cattle transactions in the country (Bowman, 2016; Klingler et al., 2018). Rural

properties are required by the 2012 Forest Code (Federal Law 12,651) to register in the CAR, which serves as a fairly complete cadaster of rural properties, although the self-declared nature of most registrations imparts a certain amount of noise and imprecision. We note that GTA records may be submitted for self-declared CAR properties even when in noncompliance with the law, such as for those located inside of SPAs or ILs. While self-declared CAR entries are expected to eventually undergo government validation, we do not make a distinction between validated and provisional CAR boundaries because slaughterhouses accept both types for supply-chain monitoring. The other property-level databases are validated by the government and are thought to be more precise.

We used entity matching to link GTA records to specific property maps based on a set of rules to match strings from multiple fields such as owner name, owner ID number, property name, and municipality present across these datasets. Groups of records were built from pairs of observations that satisfied one or more matching rules (Table S1); these records were considered to pertain to a single property and were labeled as such (see Supplementary Material for details).

We then extracted a subset of our database that included cattle transactions during 2013–2018 (the period for which GTAs were accessible from government websites in all three study region states) that originated on a property that overlaps with a PA and had as destination (1) a slaughterhouse or (2) another property (i.e., fattening farms outside PAs), as well as (3) those that were sold from other properties to PA properties. We identified the properties that were at least partially located inside PAs following the rules set by the Unified Protocol (MPF, 2020). We also tracked the transactions between fattening farms and slaughterhouses to trace the heads of cattle indirectly linked to PA properties. We included additional information for each observation including annual deforestation area and information about the inspection level (federal [SIF], state [SIE], or other [including municipal inspection and those that are uninspected; Table S2]). For some analyses, we also included additional details about slaughterhouses' CA status because G4 signatories represent the largest meatpacking companies and the earliest adopters of CAs and may have had more robust monitoring systems than TAC-only signatories (Grabs et al., 2021).

We quantified the volume of cattle listed in the GTAs associated with each type of transaction described above. For the "indirect transactions," i.e., involving cattle raised in PA properties that have reached the slaughterhouses through fattening farms, we first quantified the volume of cattle that were moved to fattening farms from the PA properties. We then quantified the number of cattle from the relevant fattening farms that were sent to slaughter within the subsequent two years. The two-year interval is based on a typical slaughter age of ~36 months, discounting the time the cattle spend on calving ranches before reaching the fattening farms (McManus et al., 2016). Because most direct suppliers sourced cattle from multiple properties (both inside and outside PAs), we considered the volume of cattle sold to slaughter via PA properties acting as indirect suppliers to be the smaller of either the volume sold from the PA properties to the fattening farms, or the total volume sold to slaughter by properties that bought cattle from PA properties. Finally, to estimate the volume of cattle from PA properties that reached CA slaughterhouses, we allocated PA cattle equally among the slaughterhouses that purchased cattle from the same fattening farm during the study period.

We restricted our analysis of indirect transactions to properties that transacted with direct suppliers, which we call "tier-1 indirect suppliers." There are additional tiers of indirect suppliers in the supply chain before the cattle reach the slaughterhouses in some instances. For example, cattle could move from a tier-2 to a tier-1 indirect supplier, then to a direct supplier, and finally to a slaughterhouse. During our study period, 85% of the GTA-listed properties acted as a direct supplier or as a tier-1 indirect supplier at least once. Hence, our approach is conservative but still identifies most of the GTA-listed PA properties in our study region.

Deforestation inside the GTA-listed PA properties was mapped for 2008–2018 using the PRODES data (INPE, 2021). We focused on the post-2008 deforestation because it matches the cutoff adopted for the monitoring of CAs (i.e., August 1, 2008; MPF, 2020). In addition, we used land cover/use data from MapBiomas (v.4.1) from 2018 to identify the PA properties with significant pasture area (> 25 ha).

3 | RESULTS

Cattle production continues in Brazil's PAs and feeds major cattle supply chains. We identified 19,782 properties registered in our spatial database that overlap with 115 SUPAs, 54 SPAs, and 91 ILs in Mato Grosso, Pará, and Rondônia states (Figure 1). Of these, 9150 (46%) had >25 ha pasture in 2018, which suggests they may have been producing cattle at some point. However, only 3878 properties (20%), across 65 SUPAs, 26 SPAs, 48 ILs, could be linked to GTA transactions during our study period. Among these 3878 properties, 1941 (51%) had post-2008 deforestation.

Of the 60.5 million head that were slaughtered in our focal states during 2013–2018, at least 3.3 million (5% of

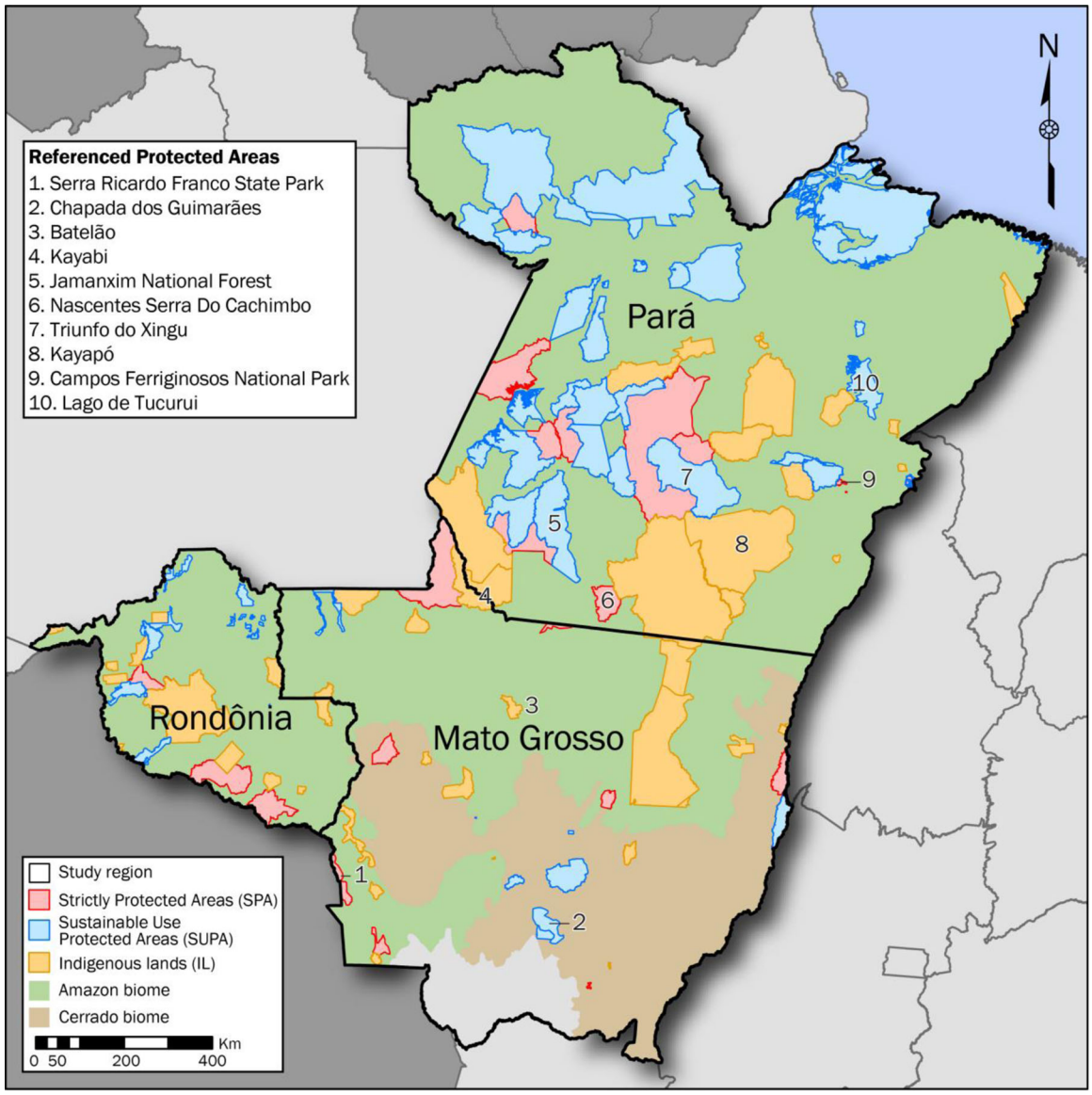

FIGURE 1 Protected areas from Mato Grosso, Pará, and Rondônia states with private properties linked to GTA transactions from 2013 to 2018

all head slaughtered in the focal states) were likely partially raised inside PAs, with SUPAs accounting for 72% of these head, followed by SPAs (20%), and ILs (8%; Figure S1). Furthermore, we estimate that 2.8 million (86% of the 3.3 million head) reached CA slaughterhouses during the study period (Figure S2).

Among the SUPAs, the largest suppliers of the 3.3 million head that reached the slaughterhouses during our study period—either directly or indirectly—were from the *Triunfo do Xingu* (33%), *Lago de Tucurui* (8%), and *Chapada dos Guimarães* (6%) environmental protection areas and the *Jamanxim* national forest (6%). The largest SPA suppliers were the *Serra Ricardo Franco* state park (10%), *Nascentes Serra Do Cachimbo* biological reserve (3%), and *Campos Ferriginosos* national park (2%), whereas the largest IL suppliers were from the *Kayabi* (2%), *Kayapó* (2%), and *Batelão* (1%) territories.

3.1 | Slaughterhouses buy directly from properties inside PAs

Despite their public commitments, some CA slaughterhouses have repeatedly purchased cattle directly from properties within PAs. During 2013–2018, 227 slaughterhouses (68 federally inspected, 30 state-inspected, and 129 municipal-inspected or uninspected; Figures 2 and S3) purchased 1.1 million cattle head directly from 1982 PA properties, with 72% of these farms located in SUPAs, 19% in SPAs, and 6% in ILs. These properties were distributed

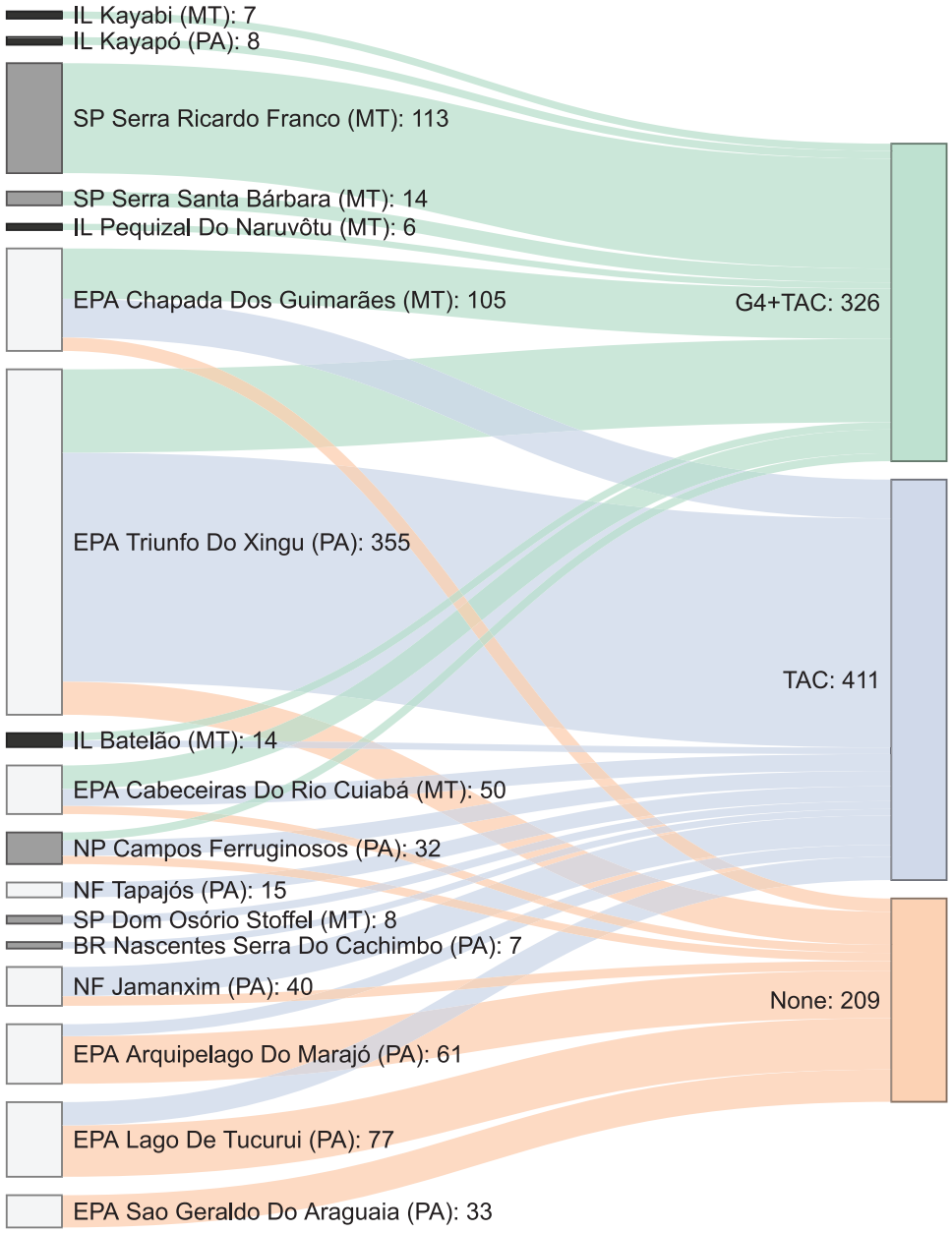

FIGURE 2 Cattle sold by farms inside protected areas (PAs) in Mato Grosso (MT), Pará (PA), and Rondônia (RO) states to slaughterhouses, from 2013 to 2018. Light to dark gray on the left bars represent sustainable-use PAs, strictly PAs, and indigenous lands, respectively. Slaughterhouses are grouped based on cattle agreements (right bars). Only flows involving ≥1000 head per year are presented to improve visualization. Numbers indicate 1000-cattle head units. Note: EPA = environmental protection area; NF = national forest; NP = national park; SP = state park; BR = biological reserve; IL = indigenous land

across 42 SUPAs, 21 SPAs, and 27 ILs. CA slaughterhouses purchased 0.86 million head from PAs during 2013–2018 (80% of the 1.1 million head), out of which 77% originated from SUPAs, 19% from SPAs, and 5% from ILs.

While the CAs initially banned (or at least limited) cattle purchases from any PAs, cattle may be legally raised one farms within certain SUPAs (MPF, 2020). Still, 27% of the cattle that reached CA slaughterhouses were sold directly by properties located inside SPAs or ILs during our study period. Furthermore, we observed post-2008 deforestation on 884 (45%) of the 1982 PA properties in our database, including 542 (48%) of the 1132 PA properties that have sold cattle to CA slaughterhouses, which should have resulted in market exclusion for any properties within SUPAs.

Nearly half of the cattle sold directly to slaughterhouses from PA properties originated from the *Triunfo do Xingu* (33%; SUPA) and *Chapada dos Guimarães* environmental protection areas (10%; SUPA) and from the *Serra Ricardo Franco* state park (12%; SPA). Two properties, located inside *Chapada dos Guimarães* and *Serra Ricardo*

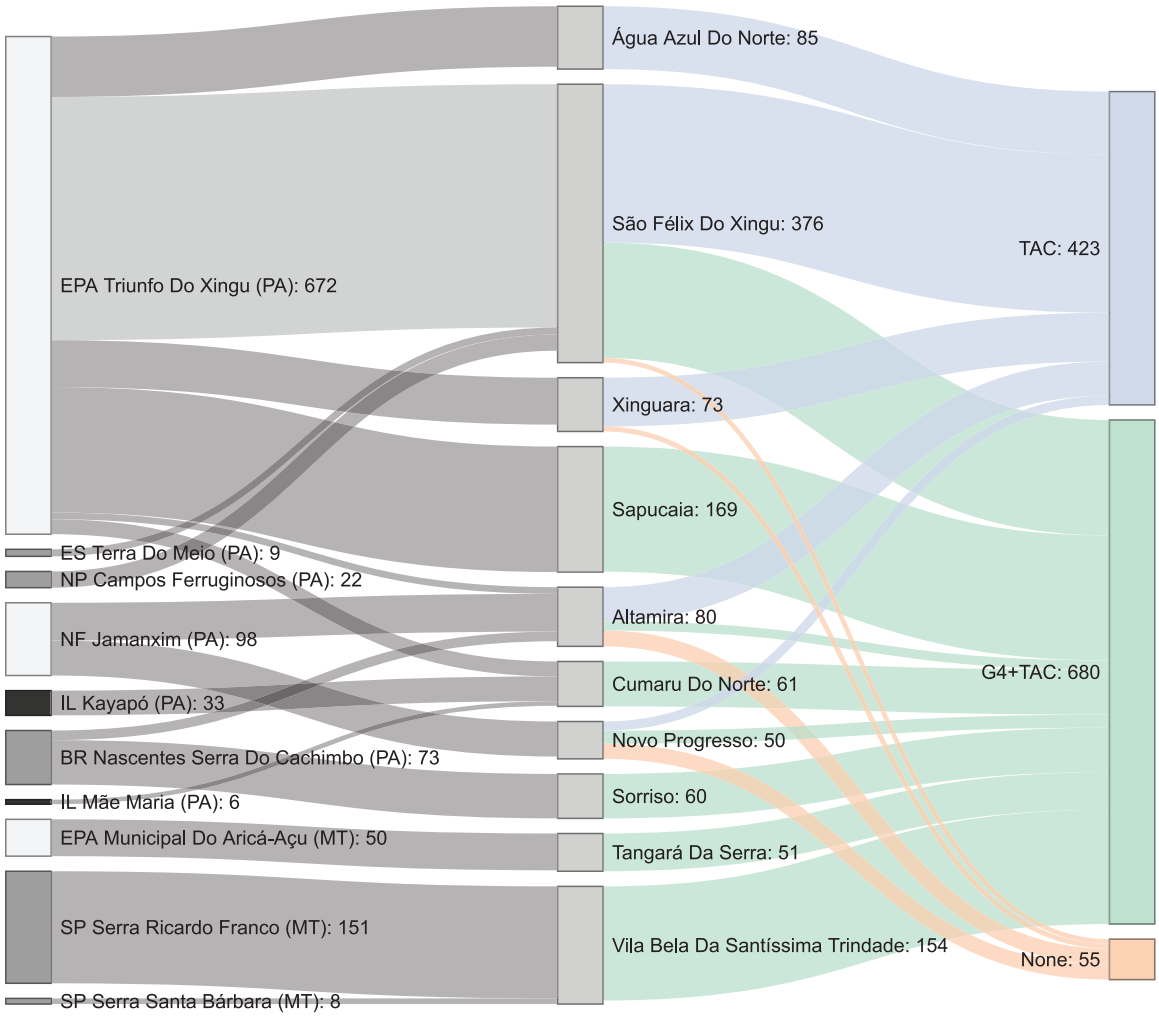

FIGURE 3 Cattle raised inside protected areas (PAs) from Mato Grosso (MT), Pará (PA), and Rondônia (RO) states and sold to fattening farms and, subsequently, to slaughterhouses, from 2013 to 2018. Light to dark gray on the left bars represent sustainable-use PAs, strictly PAs, and indigenous lands, respectively. Fattening farms are grouped based on which municipality they are located (middle bars). Slaughterhouses are grouped based on CA status (right bars). Only the transactions involving the top 10 municipalities are displayed to improve visualization. Numbers indicate 1000-cattle head units. Note: EPA = environmental protection area; NF = national forest; NP = national park; SP = state park; BR = biological reserve; ES = ecological station; IL = indigenous land

Franco, supplied 7% and 5% of the 1.1 million head to the slaughterhouses during our study period, respectively. All other PA properties contributed less than 5% of the total head sold directly, with an average contribution of 0.05% (± 0.23%SD).

3.2 | Most cattle raised in PAs are sold to slaughterhouses indirectly

Slaughterhouses' greatest exposure to illegal cattle comes from indirect suppliers. We identified 3061 properties, from 53 SUPAs, 23 SPAs, and 39 ILs, that sold cattle to 6315 fattening farms located outside of PAs, which in turn sold cattle to 375 (100 federally inspected, 39 state-inspected, and 236 municipal-inspected or uninspected) slaughterhouses (Figures 3 and S4). Nearly half (57%) of the indirect suppliers located in PAs also acted as direct suppliers during 2013–2018. In total, these 6315 direct suppliers sold 9 million head to slaughterhouses, out of which we estimate 2.2 million (24%) were at least partially raised in PAs (71% in SUPAs, 20% in SPAs, and 9% in ILs).

Of the 3061 PA properties that acted as indirect cattle suppliers, 1497 (49%) had post-2008 deforestation. These properties supplied 55% of the 2.2 million head that reached slaughterhouses, making them problematic on at least two counts. We estimate that approximately 87% of the cattle sourced indirectly from PAs were finished at federally inspected slaughterhouses and 83% reached slaughterhouses with CAs (Figures 3 and S4).

One-third of the fattening farms that purchased the 2.2 million head were from the municipalities of São Félix

do Xingu (17%; Pará state), Sapucaia (8%; Pará state), and Vila Bela da Santíssima Trindade (7%; Mato Grosso state; Figures 3 and S4). Similar to the direct transactions, about half of the cattle that reached slaughterhouses from PAs originated from the *Triunfo do Xingo* (33%; SUPA) and *Lago to Tucurui* environmental protection areas (9%; SUPA) and from the *Serra Ricardo Franco* state park (9%; SPA). One property, from *Triunfo Do Xingu*, supplied 7% of the 2.2 million head to the slaughterhouses. That was the only property that supplied more than 3% of the total headcount. All other PA properties had an average contribution of 0.03% (± 0.16% SD).

4 | DISCUSSION

PAs have long been a cornerstone of Brazil's environmental policies in the Amazon, with widely demonstrated benefits for local livelihoods, climate regulation, and especially for biodiversity conservation (Ferreira et al., 2014; Barlow et al., 2016; Nolte et al., 2013; Walker et al., 2020). We show that encroachment from cattle production continued to threaten PAs nearly a decade after the widespread implementation of the CAs, which expressly prohibit cattle purchases from these areas, especially in SPs and ILs and in SUPAs without detailed documentation. Our findings highlight the urgent need for renewed efforts to strengthen both public and private-sector policies targeting cattle supply chains in the Amazon.

Our conservative estimates show that at least two times as many cattle raised in PAs reached slaughterhouses through indirect suppliers than through direct suppliers. These results are consistent with previous studies that demonstrated the role played by indirect suppliers in funneling deforestation into supply chains (Rajão et al., 2020; Skidmore et al., 2021). Because monitoring systems currently used by slaughterhouses fail to effectively track indirect suppliers, even slaughterhouses with robust monitoring systems for direct suppliers cannot fully avoid purchasing cattle raised on PAs. An additional challenge faced by the cattle sector is the prevalence of properties with significant pasture areas identified via remote sensing but that do not appear in the GTA records (Skidmore et al., 2021). These properties suggest that our estimates are conservative and that there is potential for cattle laundering or clandestine production (Kröger, 2020; Walker et al., 2013), which are notoriously difficult to document.

Monitoring indirect suppliers has been technically challenging and continues to be hampered by data transparency issues, though solutions are emerging (JBS, 2021; Mano, 2021; Krauss et al., 2019). Promisingly, recent public sector efforts have led to the Selo Verde ("Green Stamp") tool from Pará (SEMAS, 2021) and industry led efforts created the GTFI Boas Práticas ("Good Practices") for monitoring indirect suppliers that can be implemented by the Visipec monitoring tool, all of which apply a similar approach to matching GTA and CAR as we used in this study (GTFI, 2019; Visipec, n.d.). These new initiatives increase the options available for both government agencies and companies to expand their monitoring of environmental compliance on cattle ranches. Widespread adoption of indirect supplier monitoring and elimination of illegal cattle sourced from identifiable PA suppliers would demonstrate the sector.s commitment to conservation and to maintaining consumer confidence.

Illegal production in PAs remains a critical problem in the Amazon despite important progress over the last decade in governance of Brazil.s cattle sector (Amnesty International, 2019). Growing awareness of the role of beef production in deforestation, as well as the increasing international demand for sustainable agricultural goods, have placed Brazil's cattle sector and government under heightened pressure to comply with the CA market requirements (Walker et al., 2013; Lambin et al., 2014; Pendrill et al., 2019; zu Ermgassen et al., 2020). Our results highlight the urgent need for strengthened monitoring of direct and especially of indirect suppliers across all slaughterhouses. However, we also show that the impacts of commercial cattle production are unevenly distributed across the PAs. Nearly 75% of the cattle within our study region that reached slaughterhouses during 2013–2018 originated from only seven SUPAs and one SPA. This finding aligns with previous research showing that some types of PAs offer greater protection from deforestation than others (Nolte et al., 2013). However, identification of clusters like these also highlights key opportunities for policymakers to craft targeted interventions, which can result in quicker and more effective outcomes needed to protect critical biodiversity, reduce carbon emissions, and support regional climate benefits generated by forests (Richards, 2018).

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CONFLICT OF INTEREST

L.R., J.M., and H.K.G. have an ongoing consulting relationship with the National Wildlife Federation, which is also a partner on the projects supported by the funding sources listed above and on the development of the Visipec cattle traceability tool. The National Wildlife Federation did not provide editorial oversight over the contents of this manuscript.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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