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Commodity production in Brazil: Combining zero deforestation and zero illegality

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Abstract

This article documents the degree of noncompliance of soy producers in the Amazon portion of Mato Grosso with Brazil's Forest Code and addresses the importance of market demands in shifting agricultural production and land occupation towards zero deforestation. By using a sample composed of the boundaries of 9,113 properties (72.5% of soy in the region) we assessed: a) compliance with Forest Code legal reserve requirements (a percentage of the property must have its original vegetation kept undisturbed); and compared it to b) compliance with the zero deforestation criterion of the soy moratorium. We found that 82% of the sampled properties have not deforested since 2008, thus complying with the soy moratorium. However, approximately 65% out of these 82% are noncompliant with Forest Code legal reserve requirements. This situation is even worse in the Cerrado portion of Mato Grosso. Even though the soy moratorium criterion is only applicable to the Amazon biome, the Forest Code is applicable nationwide. Despite legal reserve requirements being much lower (35% of the property in the Cerrado, as opposed to 80% in the Amazon), almost 70% of sampled properties were noncompliant with the Forest Code. From this analysis we concluded that while there was a role for consumer-driven market demand for zero deforestation soy production, there is still a need (and opportunity) to implement purchasing and financing criteria to promote compliance with Forest Code requirements in regards to legal reserve deficits. We believe that if this succeeds, it will drive a process of restoration and compensation of Forest Code deficits, strengthening public policy as well as reducing economic distortions between those who have and have not complied with Forest Code requirements.

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Introduction: Towards zero deforestation

The last eight years have been marked by drastic reductions in deforestation rates in the Brazilian portion of the Amazon biome. The annual deforestation rate measured by PRODES[1] in 2014 (484,000 hectares) was 75% lower than the average between 1996 and 2005 (1.95 million hectares/year) [2]. This reduction has been attributed to a number of factors, principally to state and federal public policies (Angelsen, 2010), as well as to improvement in environmental governance (Assunção et al., 2012; Hargraves and Kis-Katos, 2013; Rosa et al., 2013; Arima et al., 2014; Nepstad et al., 2014). Market forces have also played a role in the reduction of deforestation through initiatives such as the soy[3] and beef[4] moratoria in the Brazilian Amazon (Gibbs et al., 2015a, 2015b). This change in the Brazilian context was a response to social pressure on markets such as the European market, as well as local action taken by Amazon state public attorneys and non-governmental organizations (Brannstrom et al., 2012; Nepstad et al., 2014).

Even though there is a possibility that deforestation rates in the Amazon biome may increase again (IPAM, 2013; Nepstad et al., 2014), most commodity buyers realize that consumers have become more reluctant to purchase products from recently deforested areas and recognize that consumers are the primary force shaping markets (DNV GL, 2014). Therefore, these companies are positioning themselves against deforestation as a strategy to reduce their financial and reputational risks as well as contributing to long-term sustainability

strategies. Positions such as those expressed in the United Nations New York Declaration on Forests[5] (September 2014), expressing the political agreement by companies and countries to end deforestation, represent strong signals of change and a positive vision with regard to tropical forest conservation. Part of this movement is supported by important groups of companies such as the *Consumer Goods Forum*[6], which promises not to buy products derived from deforestation after 2020, and other initiatives, such as the Tropical Forest Alliance (Climate and Land Use Alliance, 2014).

From a scientific point of view, many studies show that forests are important not only for the conservation of biodiversity, but also to preserve the global climate (Millennium Ecosystem Assessment, 2005; IPCC, 2013, 2014; Trumbore et al., 2015). On a regional scale, forests regulate temperature and generate conditions conducive to local rainfall, and there is evidence that deforestation is already impacting local rainfall conditions (Macedo et al., 2013).

From an economic standpoint, Brazil has over 200 million hectares of pasturelands (IBGE, 2006). A significant portion (50 to 70 million hectares) could be used by agriculture, provided that cattle farming increases its productivity and average stocking rate to 1.5 head of cattle per hectare (de Gouvello, 2010; Soares-Filho et al., 2012), to ensure the provision of agricultural goods without the need for any new deforestation in coming decades (Sparovek et al., 2010; Soares-Filho et al., 2014; Angelsen, 2010). Pasturelands are currently producing only approximately 33% of their potential, and if this were to increase to 51%, producers could meet market demands until at least 2040 without the need for further deforestation. Furthermore, with improved technologies and increased productivity, beef production could increase on smaller areas of land, thus freeing up land for other agricultural uses. An estimated 36 million hectares could be freed up in the Brazilian Legal Amazon (LA)[7] alone by increasing productivity to 70% of the average pastureland carrying capacity (Strassburg et al., 2014). Within the Legal Amazon, the area of soy plantations could increase by six times if cultivated in previously deforested and underutilized areas (Gibbs et al., 2015b). For all the exposed reasons, eliminating deforestation would not negatively affect Brazil or the Amazon socially, politically or economically. Traditional food production or geopolitical reasons no longer justify further deforestation.

A report by the DNV GL certification body (2014) representing over 2,000 professionals from various companies worldwide concludes that the main driver of sustainability-related actions and initiatives is customer demand. Consumer-driven market demand is a key factor that can contribute to eliminating deforestation. This hypothesis is corroborated by the soy moratorium experience in the Brazilian Amazon. The soy moratorium initiative has played a role in inhibiting soy expansion into forested areas (Gibbs et al., 2015b). We argue that if consumer-driven market demand has helped to virtually end deforestation in the soy supply chain in the Brazilian Amazon, this same strategy could be used to foster compliance with the Forest Code by demanding restoration or compensation of deficits of legal reserve and permanent protection areas. We aim to show that while many private properties have not deforested since 2008, they do not comply with legal reserve requirements of the Forest Code, and in that sense, are illegal. Furthermore, we suggest that the first step towards compliance with the Forest Code is for property owners join the Rural Environmental Registry (CAR in Portuguese), the main instrument to monitor Forest Code compliance. We end by arguing that consumer-driven market demand should be used to stimulate property owner adhesion to the CAR land registry and compliance with the Forest Code. Currently producers are not incentivized to adhere, but instead discouraged because of environmental liability exposure and threats of sanctions. Therefore consumers' demand for CAR works as an incentive for environmental compliance.

The Brazilian Forest Code and illegality

The main purpose of the Brazilian Forest Code is to regulate land use on private properties. The Forest Code was first introduced as a federal regulation in 1934 by Decree 23,793[8], establishing percentages of private properties in which native vegetation must be maintained. This law was revised four times: Law No. 4,771[9] in 1965, provisional measure (MP in Portuguese) No. 1,511[10] in 1996, MP No. 2,166–67[11] in 2001; and finally Law No. 12,651 in 2012[12]. Our purpose is not to discuss changes that have occurred in the Forest Code[13], rather we will focus on the current 2012 version.

Two main components of the Brazilian Forest Code regulating forest conservation on private lands are the legal reserve (LR) and permanent protection areas (PPA). The legal reserve is the proportion of the property that must be maintained in native vegetation and may include permanent protection areas such as riparian zones and hilltops.[14] For the Brazilian Amazon, the legal reserve is required to constitute 80% of the property area (leaving 20% for other activities), except: a) where economic and ecological zoning (ZEE in Portuguese) is in place; b) on properties which had a 50% legal reserve in 2001 and have not cleared additional land; and c) on small properties (up to four fiscal modules[15]) that have not deforested after July 2008 even though they had legal reserve deficits at the time. For properties in the Cerrado biome within the Legal Amazon, the legal reserve requirement is 35% of property area (leaving 65% for other activities), except on properties which had 20% legal reserve requirements in 2001, or on small properties (up to four fiscal modules) that have

Table 1. Definitions of terms and acronyms

Concept	Acronym	Definition
Legal reserve	LR	Proportion of the property which should be maintained with native vegetation and which may include PPA areas.
Permanent protection area	PPA	Riparian zones of rivers and hilltops that must be protected. They can compose the LR as long as it is not used for the purpose of freeing forestland for conversion.
Fiscal modules	FM	Criterion established by INCRA (National Institute for Colonization and Agrarian Reform) to classify properties in small (less than four FM), medium (between four and fifteen FM) and large (greater than fifteen FM). One fiscal module may vary between 30 and 100 hectares, depending on the municipality. This classification criterion considers predominant type of rural activity in the municipality, income generated with this predominant type of rural production activity and other crops produced in the municipality.
Rural environmental registry	CAR[a]	Geo-referenced identification of property perimeter as well as the perimeters of the legal reserve and permanent protection areas.
Environmental reserve quotas	CRA[b]	Tradeable land use permits issued by properties that have LR surpluses. One quota is equivalent to one hectare of LR surplus. This mechanism allows for the conservation of native vegetation on properties with excess forest areas through sale of this permit to properties that need to compensate their legal reserve deficits.
Legal Amazon	LA	Political boundary used by the Brazilian Institute for Geography and Statistics (IBGE, in Portuguese) to characterize states from the Amazon region. Within the nine states of the Legal Amazon, there are areas of Amazon and Cerrado biomes. The states that compose the Legal Amazon are: Pará, Mato Grosso, Tocantins, Rondônia, Acre, Amapá, Roraima, Maranhão and Amazonas.
Soy moratorium	SM	Agreement between civil society, industry and government to halt conversion of forestlands in the Amazon biome to soy plantations. If a producer grows soy on an area deforested after July 2008 in the Amazon biome, he becomes unable to trade with companies associated with ABIOVE (Brazilian Association of Vegetable Oil Industries) and ANEC (Association of Cereal Exporters in Brazil). These two associations represent about 90% of the soy market share.

[a]Acronym in Portuguese, from *Cadastro Ambiental Rural.*
[b]Acronym in Portuguese, from *Cota de Reserva Ambiental.*
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not deforested after July 2008 even though they had legal reserve deficits at the time. In all other Brazilian biomes, the legal reserve requirement is 20%.

The second component, permanent protection areas (PPA), differs from the legal reserve as they are composed of riparian zones of rivers and hilltops. PPAs can be part of the legal reserve as long as they are not used for the purpose of freeing forestland for conversion. The most important aspect of PPAs is that they provide absolute protection for the most environmentally sensitive areas, especially water and biodiversity ecosystem services (Lima et al., 2014) (see Table 1 for definitions of terms and acronyms). In other words, PPAs are not a percentage of the total property area that must be maintained as is the case with the legal reserve, but rather are sensitive areas that must be maintained regardless of property size.

If rural properties are judged noncompliant with legal reserve requirements, they can be considered 'illegal', in two respects. First, they can have legal reserve deficits, implying that they do not have the Forest Code-required percentage of native vegetation set aside on the property. Second, they can have degraded PPAs, meaning that they do not have appropriate native vegetation covering their riparian zones and hilltops. If the liability is related to PPAs, these areas must be fully restored according to the Forest Code. However, if the noncompliance is related to the legal reserve that was deforested before July 2008, there are two options to become compliant: a) restore the area of legal reserve deficit through directed restoration or through natural regeneration; or b) compensate by acquiring equivalent tradeable land use permits issued by properties that have legal reserve surpluses (Environmental Reserve Quotas, CRA in Portuguese).

However, if deforestation took place after July 2008, the only option is to restore these areas through directed restoration or natural regeneration. In the case of properties that have legal reserve surpluses, they can request that the state environmental agency issue a license to deforest or to issue a tradeable land use permit (CRA) and compensate equivalent legal reserve liabilities on other properties located within the same biome (Soares-Filho et al., 2014).

In this analysis, we looked only at compliance with legal reserve requirements, due to the lack of adequate data for geographical identification of PPAs and degraded PPAs, and the level of uncertainties involved (Law No. 12,651/2012) [16]. Therefore, when we refer to 'illegality' we mean noncompliance with Forest Code legal reserve requirements. More importantly, a property can be free from deforestation as of a given cut-off date, for example July 2008 as the soy moratorium determines, but the same property can be 'illegal' or noncompliant with the Forest Code if it has a legal reserve deficit or degraded PPA.

Despite relaxed standards adopted in the latest revision of the Forest Code (2012), there are still large areas of legal reserve deficits. There are from 21 to 24 million hectares of legal reserve and permanent protection areas needing restoration. This land area has the potential of sequestering approximately 9.1 billion tons of CO_2e (Soares-Filho et al., 2014). Also, the new Forest Code introduced a very important policy instrument for monitoring implementation: the Rural Environmental Registry, known as CAR in Portuguese (Figure 1). This instrument was promulgated in 2014[17] and by August 2015, almost 234 million hectares in more than 1.8 million rural properties were already registered in the federal CAR database.[18] The CAR is a geo-referenced identification of property boundaries as the legal reserve and PPA boundaries. All these boundaries compose a Geographic Information System (GIS) database with information of land owners in the attribute table. With this registry, it is possible to monitor Forest Code compliance using spatial data on deforestation, such as INPE's PRODES.[19] In other words, the CAR is the first step towards compliance with the Forest Code by allowing state and federal environmental agencies to verify and monitor the percentage of native vegetation on each private property (Azevedo, 2009; Rajão et al., 2012). Approximately 281 million hectares of native vegetation are within the scope of the Forest Code. This corresponds to a carbon stock of roughly 84 billion tons of CO_2e (Soares-Filho et al., 2014) and this number is equivalent to fifty years of Brazil's annual (2013) emissions of greenhouse gases.[20]

It is important to note that the CAR is a self-declaration on the part of the property owner. After registration of property perimeters in the CAR database, validation is carried out by state environmental agencies, resulting in two paths for property owners: 1) if they fulfill all of the requirements, the CAR is validated and has an "active" status; and 2) if not, the CAR is put on "stand-by". Under this second scenario, the landowner must adhere to a plan for restoring degraded areas (PRA in Portuguese), committing to resolve environmental liabilities such as legal reserve or PPA deficits, so that the CAR can become active again. Registering properties in CAR is mandatory for every single rural establishment in Brazil, whether productive or not. Therefore what had been considered an obstacle to agricultural production can become a tool allowing consumers and industry to identify deforestation and illegality on each of their suppliers' properties.

The legal regime brought about by the new Forest Code (2012) and increasing recognition on the part of market forces and banks that deforestation (legal or illegal) [21] should be excluded from commodity production are huge new challenges. How can supply chains be verified to be free of deforestation and also in compliance with Forest Code legal reserve requirements? Currently, markets and banks do not differentiate whether a property is in compliance with the Brazilian Forest Code or not. Producer "A" who has 80% (or 50% depending on the case) of his property in legal reserve (compliant with the Forest Code legal reserve requirements) is not considered differently than producer "B" who only has 5% of his property in legal reserve, even though both may be in compliance with the soy moratorium if they have not deforested since 2008. Both can sell to the same companies and thus, legal products are mixed with illegal products without any differentiation or distinction. The analysis presented here illustrates this by showing the difference between zero deforestation after 2008 and zero illegality in Mato Grosso state.

Methodology

Mato Grosso State was selected as a case study due to its status as the largest soy producer in Brazil and for having a frontier of agricultural expansion northwards into the Amazon biome. Moreover, sufficient geospatial data was available to map property boundaries and annual deforestation rates.

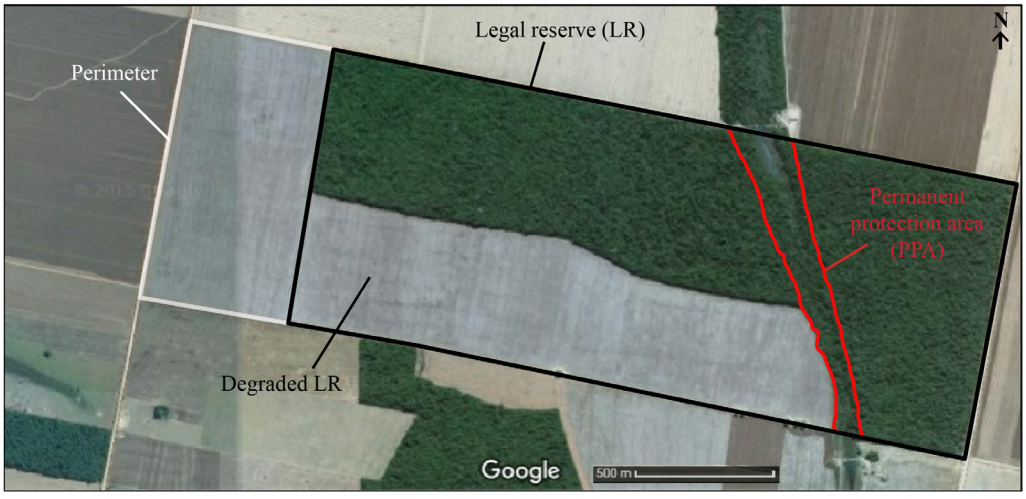

Figure 1

Example of a property in the Rural Environmental Registry.

Rural Environmental Registry (CAR in Portuguese) is an instrument instituted by the Forest Code (2012) to register and monitor environmental compliance of properties. It is basically a geo-referenced identification of property boundaries, including the boundaries of the legal reserve and permanent protection areas. Source of image: google maps.

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Table 2. Summary of primary data sources used in this article

Type of dataset	Source of dataset
Property boundaries	CAR-MT (2014); LAU-MT (2012); INCRA (2014); Terra Legal (TL)/SERFAL (2014).
Deforestation	PRODES/INPE (2014); SIAD/UFG (2014); PMDBBS/IBAMA (2009).
Soy area	Macedo et al. (2012) – soy maps for 2001-2010; IMEA (2014) non-spatial soy area (in hectares), production (in tons) and productivity (in tons/hectare).
Other data sources	IBGE (2006) – agricultural census data: total number and area (in hectares) of rural establishments in Brazil.

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Data

Brazil does not yet have a comprehensive database of all rural property boundaries, thus for this study we used a combination of several geospatial datasets. The first group of datasets is aimed at identifying property or land occupation boundaries: 1) CAR-MT (2014)[22], 2) LAU-MT (2012) [23], 3) INCRA's Certified Rural Private Lands (INCRA, 2014) [24], and 4) land occupation geo-referenced by the Terra Legal Program (SERFAL, 2014).[25] Considering that none of these datasets can stand alone as the most accurate, they were combined to increase accuracy, as described in *Data Processing* and by Text S1, Text S2, Text S4, Table S1 and Table S2 in the Supplemental Material.

The second group of datasets refers to spatial and temporal deforestation data. This is a dataset called PRODES[26] published annually by INPE[27] containing deforestation polygons in the Brazilian Amazon. This dataset is composed of annual incremental deforestation polygons. For the Cerrado, two datasets were combined: a) PMDBBS[28]/IBAMA[29] (2009), with accumulated deforestation data up to 2002, and b) SIAD[30] data from LAPIG/UFG[31] (2014) with annual deforestation increments from 2003 to 2014 (Text S3).

The third group of data used refers to mapping of soy expansion in Mato Grosso between 2001 and 2010 by Macedo et al. (2012). (See Table 2 for a summary of data sources used). The total area shown for planted soy was validated with APROSOJA[32] figures (IMEA[33], 2014), which are not spatial. Total areas indicated by both datasets are almost the same and the spatial soy data by Macedo et al. (2012) intersected with property boundaries[34] was found to be 71.7% of the total area of soy indicated by IMEA (2014) for 2010 in Mato Grosso. Also, IBGE[35] (2006) agricultural census data was used as a rough indicator of sample representativeness by showing how many rural establishments are identifiable in comparison to the land boundaries identified in those datasets. As a result, 43.2% of rural properties were found in number and 93.7% in area (Text S4).

Data processing

Property boundary datasets had overlaps within themselves and among each other. Therefore several cleanup operations needed to be executed to eliminate these overlaps (see Text S4). The operations with deforestation data basically involved transformations from vector to raster and raster calculator in order to compose a final raster dataset with deforestation information in the Amazon and Cerrado biomes of Mato Grosso (see Text S3). Then the 2010 soy map by Macedo et al. (2012) was spatially joined to identify properties with soy. Finally, for the purpose of classifying properties according to fiscal modules and biomes, a biome vector layer (MMA, 2015) was spatially joined into the dataset as well as a shape file with all of the Mato Grosso municipalities (IBGE, 2015) and joined in a table providing information on fiscal modules for each municipality (see Figure S1).

Data analysis and interpretation

An analysis of compliance with Forest Code legal reserve requirements was undertaken. The new Forest Code (Law No. 12,651/2012) revised the former Forest Code (Law No. 4,771/1965), making some changes in legal reserve requirements. These changes were incorporated into the analysis in three primary ways: 1) extent of the legal reserve, which is 80% of native forestland and 35% of native Cerrado lands within properties in the Legal Amazon[36]; 2) property size class, which can be small (up to four fiscal modules), medium (between four and fifteen fiscal modules) and large (more than fifteen fiscal modules); and 3) when deforestation took place, because all small properties deforesting up to July 2008 were granted amnesty, as were medium and large properties that had at least 50% of property area in forestland legal reserve in the Legal Amazon in 2001, with no further deforestation (see Figure S2).

Results

Sample description

The sample described here followed the methodology proposed by the soy moratorium, where only soy properties were considered with a total area greater than 50 hectares and over 25 hectares of soy.[37] A total of 9,113 properties with soy were found in Mato Grosso in both Amazon and Cerrado biomes. These properties add up to 18,134,926 hectares in total area with 4,598,030 hectares of soy planted (25.3%). The sampled properties in the Cerrado have only 14.9% of native vegetation still conserved, whereas sampled properties in the Amazon still have about 44.6% of native vegetation conserved. This shows that about 85.1% of all native vegetation within the sampled properties in the Mato Grosso Cerrado biome has already been cleared, while 55.4% of native vegetation has been cleared in the Amazon biome. We identified and mapped almost 4.7 million hectares of the total 6.3 million hectares of soy planted in Mato Grosso in 2010, 74% of soy planted in the state (Table S3). After processing the data to minimize uncertainties[38], our sample still encompassed almost 4.6 million hectares of soy, representing approximately 72.5% of all soy planted in Mato Grosso (Table S4).

Level of non-compliance with legal reserve requirement in properties with soy in Mato Grosso

In Mato Grosso, 69.9% of the sampled properties (n = 9,113) were found noncompliant with legal reserve requirements. These 69.9% of properties represented 85.4% of the total sample area and 88.9% of the soy area. This is a total figure for both Amazon and Cerrado biomes. The aggregate area of legal reserve deficit, *i.e.*, the area needing to be restored or compensated amounts to 4,294,203 hectares (Table S5).

Disaggregating by biome: the Amazon subsample had 70% of properties noncompliant with legal reserve requirements (n = 3,291). These 70% of properties correspond to 87.5% of the Amazon subsample total area and 87.8% of the soy area. The legal reserve deficit in the Amazon to be restored or compensated amounts to 2,755,990 hectares (Table S6).

In the Cerrado, the findings were quite similar: 69.9% of sampled properties (n = 5,822) were noncompliant with Forest Code legal reserve requirements. These 69.9% of properties were composed of 83.4% of the total sample area and 89.3% of the soy area. Although the legal reserve requirement for Cerrado lands in states of the Legal Amazon is conservation of 35% of native vegetation, much less than the 80% required from Amazon properties, there are 1,538,213 hectares in Forest Code deficit status to be restored or compensated (Table S7).

Soy moratorium: Effectiveness for zero deforestation but not for compliance with forest legislation

The soy moratorium is an agreement between civil society, industry and government to halt conversion of forestlands in the Amazon biome to soy plantations. It does not yet include the Cerrado. The soy moratorium was established in 2006 and created a monitoring and enforcement mechanism that identified deforestation after July 2006 and any soy planted in these areas in any subsequent year. Soy from these noncompliant areas could not be traded by ABIOVE (Brazilian Association of Vegetable Oil Industries) or ANEC (Association of Cereal Exporters in Brazil). The companies associated with these organizations trade and purchase about 90% of all Brazilian soy production. In 2014, the agreement was renewed with a modified design and the cut-off date for deforestation moved to July 2008 in order to be coherent with the Forest Code amnesty cut-off date (Gibbs et al., 2015b).

Looking at the 3,291 sampled soy properties in the Amazon biome of Mato Grosso, 81.6% (2,686 properties) had zero deforestation after 2008. Of these 2,686 properties, however, 64.7% (1,738 properties) were noncompliant with Forest Code legal reserve requirements (Table S8). Notwithstanding, according to the criteria stipulated by the soy moratorium, all of these properties could sell their production. Considering the area used in this analysis, the environmental liability (legal reserve deficits) would amount to 1,747,745 hectares (20% of the total sample area), which would need to be restored or compensated (Table S9). This is a large legal reserve deficit and demonstrates a significant amount of noncompliance within the soy supply chain. Market mechanisms such as the soy moratorium, even though effective in reducing deforestation, are not capable of avoiding the illegality of Forest Code noncompliance, and should be rethought to include Forest Code compliance as a purchasing/financing criterion.

Were environmental legality criteria taken into account in the soy moratorium, the impact would be huge. Of the 2,686 properties that are currently trading soy through the existing mechanism because they have not deforested after July 2008, only 948 properties (35%) would be able to continue to trade (Table S8). Applying the same rationale, for about one million hectares of planted soy currently being traded through the existing mechanism, almost 862,000 hectares (85.5%) would not be able to trade, leaving only 146,000 hectares free for compliant trading.

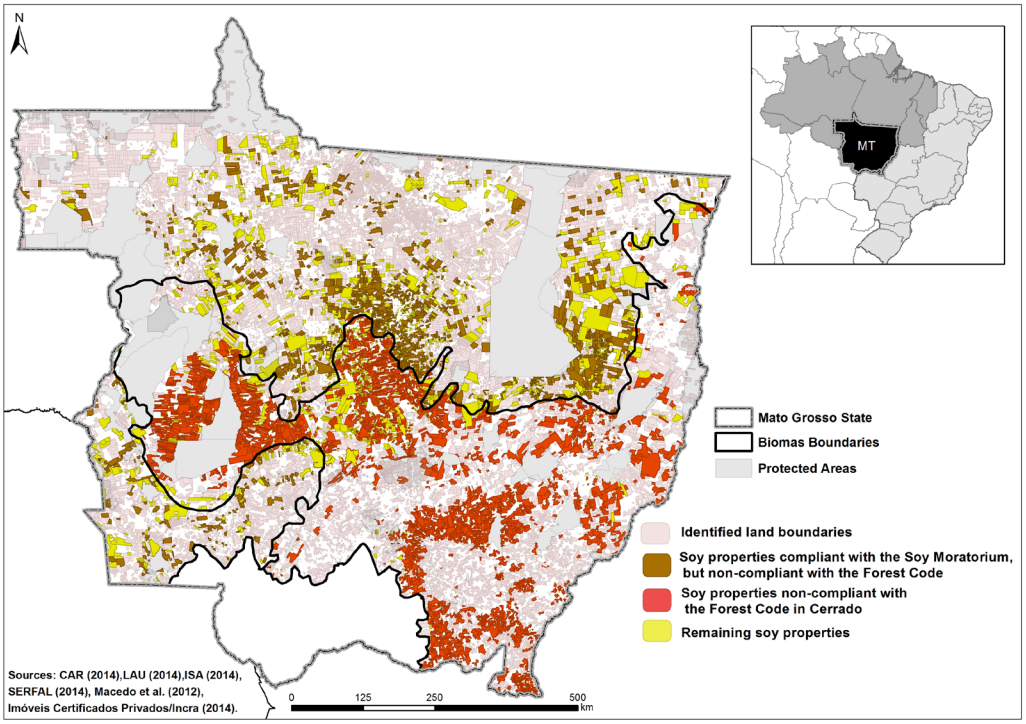

Figure 2

Compliance of soy properties in Mato Grosso with zero deforestation and the Forest Code.

This map shows soy properties in Mato Grosso, some of which comply with the zero deforestation criterion established by the soy moratorium (SM), while at the same time they are in noncompliance with the legal reserve (LR) requirements of the Forest Code (FC). The map spatially demonstrates properties that comply with the SM, but not with the LR requirement of the Forest Code in the Amazon biome (brown polygons); properties noncompliant only with the LR requirement of the Forest Code in the Cerrado biome, simply for the reason that the SM does not include the Cerrado biome (red polygons); and remaining soy properties (yellow polygons) are those: 1) noncompliant with the SM in the Amazon biome, 2) compliant with the SM and with LR requirements in the Amazon and, 3) compliant with LR requirements in the Cerrado.

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In terms of volume, the average soy productivity in 2010 in Mato Grosso was 3.1 tons/hectare (IMEA, 2014). This amounts to almost 2.7 million tons of soy traded through the moratorium but noncompliant with the Forest Code. **Only 454,000 tons of the soy produced complied with both the soy moratorium and the Forest Code**. Figure 2 illustrates the total properties, soy properties and those noncompliant with the Forest Code in the Amazon and Cerrado biomes.

Discussion and conclusions

While the soy moratorium is an industry agreement to halt deforestation in the soy supply chain in the Brazilian Amazon, the Forest Code is federal legislation regulating the percentage of native vegetation that must be maintained on private properties according to location. Given that the Forest Code allows for legal deforestation up to the percentage determined by law, there are properties with surpluses and liabilities (deficits) corresponding to legal reserve requirements. In this situation, how can industry and consumers separate what is legal from what is illegal, especially considering that properties with zero deforestation are not necessarily 'legal' and that legal deforestation is not accepted by zero deforestation commitments such as the soy moratorium? How can we avoid having something produced illegally become legal throughout the supply chain? How can industry and consumers support producers to achieve not only zero deforestation but also zero illegality?

These are not simple questions. In many cases when there are many suppliers (e.g., beef production) and there are many links in the supply chain, halting deforestation and illegality is a much more challenging task. In relation to the Forest Code, one of the challenges posed by industry has been to check whether all of their suppliers are compliant with the law. Some alternatives such as field visits are possible; however, these present relatively high costs which make implementation harder. Certification of production is a possibility, and various standards have been developed and are used (to some extent) worldwide (*e.g.* Round Table on Responsible Soy (RTRS)[39], Round Table on Sustainable Palm Oil (RSPO)[40], Bonsucro sugarcane standards[41], Forest Stewardship Council (FSC)[42] and others). Nevertheless, certification has not achieved scale for any of the aforementioned crops to date.

This is partially due to the fact that while consumers express willingness to buy certified products, they often are not willing to pay, or the premiums offered are not attractive and in some cases do not even cover certification costs. Compliance with the Forest Code through adhesion to CAR and compliance with legal reserve requirements could function as a minimum certification standard that would be made public and equally available to all companies and consumers. Once all producers have joined CAR (the deadline is May 2016) it will be possible to constantly monitor rural properties for legal reserve and permanent protection area infringements. In this sense, CAR is also a tool for transparency, allowing all companies to verify environmental legality in their supply chains independent of government actions.

This process of transforming the CAR into an ally of industry is of utmost urgency. Opportunities for industry involve cost-effectiveness to monitor supply chains because they do not need to develop and implement their own monitoring systems, as the Soy Working Group does for the Brazilian soy moratorium. Transaction costs are much smaller than private monitoring systems or certification because CAR is publicly provided and compulsory to all producers. In contrast, if industry does not demand CAR as a first step purchasing criterion, there is the risk of CAR failing as a public policy because producers do not have incentives to register, but rather disincentives as CAR will expose their liabilities. If not actively encouraged by consumers, producers tend not to adhere to CAR. Therefore industry and banks involved with commodity supply chains must start demanding CAR as criteria to purchase or finance agricultural production, thus demonstrating a commitment to maintain supply chains free of illegality. The soy moratorium is a successful case showing that the union of industry and civil society can accomplish (almost) zero deforestation in the suppliers of soybeans in the Amazon; therefore it is also possible to achieve zero illegality. In this context, the federal government must be committed to speed up and keep the CAR monitoring process transparent. Industry and consumers must use CAR as a first step to remove illegality from their supply chains.

Legislation should be complied with for two main environmental reasons, not to mention others: 1) restoration of legal reserve and PPA deficits sequester carbon, thus promoting climate change mitigation in addition to restoring other ecosystem services such as biodiversity, water, soil and nutrient cycling; 2) compensation of legal reserve deficits promotes conservation of legal reserve surpluses, which in general are primary or secondary vegetation ecosystems with high carbon stocks and all other associated services. Through the acquisition of CRAs (tradeable environmental reserve quotas) issued by properties with legal reserve surpluses, forestlands that could be legally deforested are conserved by sale of this right to deforest to other properties with deficits, thus maintaining and enhancing forest ecosystem services. Therefore it is important not only to achieve zero deforestation, but also to encourage agricultural suppliers to adjust and conform to legislation (*i.e.*, the Forest Code).

Compliance with the Forest Code is not a trivial goal, but it is possible. Companies must know that their reputation is at risk, because they could be trading illegal products, as happens currently. To leave this control up to state or federal governments is not an option, as this would not ensure legality and would leave companies and consumers vulnerable to changes in government. The existence of and compliance with legislation such as the Forest Code sends a strong signal. As long as producers are compliant with the Forest Code, it will differentiate Brazil's status among primary producers of food and feed. Brazil is in a unique position of being an agricultural powerhouse and at the same time having large areas of native vegetation preserved on private properties. In that sense, purchasing from Brazil would be a differential *per se,* because in addition to the Forest Code, there would be a single and unique system for monitoring legality and deforestation at the property level. For this to happen, first it is necessary to support CAR registration on the part of producers and second, to adjust Forest Code requirements by restoring or offsetting legal reserve deficits and restoring PPA deficits through adherence to the PRA (Program for Environmental Regularization).

In a phased approach, industry, that buys commodities, and banks, that finance production, should demand CAR registration and PRA adherence as criteria to purchase products or to finance production. This should occur for all agricultural products and not only for soy. Furthermore, it should encompass all of the biomes and not only the Amazon. It should be done within a trustworthy and transparent system, so that civil society can identify the existence of illegality and recognize the most responsible and proactive companies.

The way forward is to use consumer-driven market demand for compliance with the Forest Code as a basis for a nationwide monitoring system, with reduced risks and transaction costs (locally, regionally and nationally) for buyers of commodities as well as for banks that finance production and for consumers in general. However given that the Forest Code still allows for legal deforestation to take place, it is also necessary to have sector-wide agreements in place such as the soy moratorium in order to ensure supply chains free of both deforestation and illegality.

Legislation and public policies alone are not sufficient to stop deforestation and promote environmental compliance. For this reason state and markets must combine efforts to address these issues. States must provide legal and regulatory frameworks as well as adequate implementing capacity and markets must be partners by requiring from suppliers compliance with legislation and adequate environmental performance and also by offering positive incentives.

Further research can address the implications of noncompliance with environmental legislation to specific supply chains or markets such as beef, sugarcane, cotton, or also to specific stakeholders, such as business, traditional communities, and farmers. Transparency of data and its capacity to result in enhanced environmental governance is also an interesting topic to be covered by additional research.

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Notes

1. PRODES is a program from the Brazilian Institute for Space Research (INPE) which has measured annual deforestation rates in the Amazon biome since 1988.

2. The average between 1996 and 2005 is considered as the baseline for deforestation, therefore it is used for comparison here. The data are from PRODES/INPE (2014): http://bit.ly/1BTdPW9

3. Soy Moratorium Report (7th year): http://bit.ly/17uROjb

4. Agreement between Greenpeace and JBS: http://bit.ly/1D8erm7

5. New York Declaration on Forests: http://bit.ly/1Mq31Vk

6. The Consumer Goods Forum link: http://bit.ly/1969aEi

7. The Legal Amazon (LA) is a political designation used by the Brazilian Institute for Geography and Statistics (IBGE, in Portuguese) to characterize states from the Amazon region. Within the nine states included in the Legal Amazon, there are areas of both Amazon and Cerrado biomes. States in the LA include: Pará, Mato Grosso, Tocantins, Rondônia, Acre, Amapá, Roraima, Maranhão and Amazonas.

8. Available at: http://www.planalto.gov.br/ccivil_03/decreto/1930-1949/d23793.htm.

9. Available at: http://www.planalto.gov.br/ccivil_03/Leis/L4771.htm.

10. Available at: http://www.planalto.gov.br/ccivil_03/mpv/Antigas/1511.htm.

11. Available at: http://www.planalto.gov.br/ccivil_03/mpv/2166-67.htm.

12. Available at: http://www.planalto.gov.br/ccivil_03/_ato2011-2014/2012/lei/l12651.htm.

13. For this comparison and detailing, see Soares-Filho et al. (2014) and Lima et al. (2014).

14. However, this provision cannot be used if it leads to new conversion of forestland.

15. Fiscal Modules (FM) are a criterion established by INCRA (National Institute for Colonization and Agrarian Reform) to classify properties in small (less than four FM), medium (between four and fifteen FM) and large (greater than fifteen FM). One fiscal module may vary between 30 and 100 hectares, depending on the municipality. This classification criterion considers predominant type of rural activity in the municipality, income generated by this predominant type of rural production and other crops produced in the municipality (Law no. 8,629/1993. Link: http://www.planalto.gov.br/ccivil_03/leis/l8629.htm)

16. Available at: http://www.planalto.gov.br/ccivil_03/_ato2011-2014/2012/lei/l12651.htm.

17. Decrees No. 7,830/2012 and 8,235/2014, available at: http://www.planalto.gov.br/ccivil_03/_Ato2011-2014/2012/Decreto/D7830.htm and http://www.planalto.gov.br/ccivil_03/_Ato2011-2014/2014/Decreto/D8235.htm.

18. Brazilian Forestry Service, information available at: http://bit.ly/1MG6rOu

19. PRODES is a program from the Brazilian Institute for Space Research (INPE) which has measured annual deforestation rates in the Amazon biome since 1988.

20. SEEG 2014: http://www.seeg.eco.br/emissoes-totais/.

21. Legal deforestation is deforestation of legal reserve surplus licensed by the state environmental agency. Illegal deforestation is unlicensed land clearing or deforestation that generates a legal reserve deficit or degradation of permanent protection areas. There are no set statistics for the amount of illegal deforestation, however, it is estimated that it corresponds to 90% or more of all deforestation (Azevedo et al., 2014).

22. Rural Environmental Registry database of Mato Grosso state.

23. Unified Environmental License database of Mato Grosso state.

24. INCRA is the National Institute of Colonization and Agrarian Reform.

25. SERFAL is the Ad Hoc Secretary of Land-Tenure Clearing in the Legal Amazon.

26. Project for Satellite Monitoring of the Brazilian Amazon Forest.

27. National Institute of Space Research.

28. Project for satellite monitoring of deforestation in all Brazilian biomes.

29. Brazilian Institute for the Environment and Renewable Natural Resources.

30. Integrated System for Deforestation Alert.

31. Laboratory for Image Processing and Geo-processing/Federal University of Goias.

32. APROSOJA is the Brazilian Soy Producers Association. Their figures for area of planted soy in hectares, soy production in tons and productivity are considered very accurate as they come directly from producer reporting and monitoring, however these figures are not defined spatially.

33. IMEA is the Mato Grosso Institute for Agriculture Economics.

34. Criteria: property areas larger than 50 hectares and soy areas larger than 25 hectares to be coherent with soy moratorium monitoring.

35. Brazilian Institute of Geography and Statistics.

36. The Brazilian Legal Amazon includes the states of Amazonas, Pará, Maranhão, Tocantins, Mato Grosso, Rondônia, Roraima, Amapá and Acre. These states have Amazon forest, transitional areas and Cerrado.

37. This criterion was used to maintain consistency with the criteria of the soy moratorium (Soy Moratorium 7th year report - http://bit.ly/17uROjb).

38. Using only polygons with property area ≥ 50 hectares and soy area ≥ 25 hectares.

39. See: http://www.responsiblesoy.org/en/.

40. See: http://www.rspo.org/.

41. See: http://bonsucro.com/site/.

42. See: https://ic.fsc.org/.

Contributions

- Contributed to acquisition and processing of data: TNPR, MCCS
- Contributed to analysis and interpretation of data: AAA, TNPR, MCCS
- Drafted and/or revised the article: AAA, TNPR, MCCS
- Approved the submitted version for publication: AAA, TNPR, MCCS

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Competing interests

The authors have declared that no competing interests exist.

Supplemental material

- **Text S1. Description of land boundary datasets** doi: 10.12952/journal.elementa.000076.s001
- **Text S2. Explanation and description of results of the cleanup operations within land boundary datasets** doi: 10.12952/journal.elementa.000076.s002
- **Text S3. Description of deforestation and soy datasets and processing** doi: 10.12952/journal.elementa.000076.s003

- **Text S4. Cleanup and merging operations for land boundary datasets** doi: 10.12952/journal.elementa.000076.s004
- **Table S1. Reductions in total area analyzed after cleanup operations within the same dataset to remove overlaps between polygons, as referenced in the 'Methodology' section and 'Data' subsection of the main text, also described in Supplemental Texts S1 and S2** doi: 10.12952/journal.elementa.000076.s005
- **Table S2. Reductions in total area after removing overlaps between different property boundary datasets which were merged to compose an aggregate land boundary dataset as referenced in the 'Methodology' section and 'Data' subsection of the main text** doi: 10.12952/journal.elementa.000076.s006
- **Table S3. Overall area description of sample properties as referenced in the 'Results' section and 'Sample description' subsection of the main text, and Supplemental Text S4** doi: 10.12952/journal.elementa.000076.s007
- **Table S4. Overall description of sample properties disaggregated by biome, which are a subset of all identified properties (Table S3)** doi: 10.12952/journal.elementa.000076.s008
- **Table S5. Classification and description of soy properties according to compliance with legal reserve (LR) requirements (Amazon and Cerrado biomes aggregated) as referenced in the 'Results' section and 'Level of non-compliance with legal reserve requirements in properties with soy in Mato Grosso' subsection of the main text** doi: 10.12952/journal.elementa.000076.s009
- **Table S6. Same as Table S5, but disaggregated at the biome level, showing the classification and description of soy properties according to compliance with legal reserve (LR) requirements (only Amazon biome of Mato Grosso disaggregated) as referenced in the 'Results' section and 'Level of non-compliance with legal reserve requirements in properties with soy in Mato Grosso' subsection of the main text** doi: 10.12952/journal.elementa.000076.s010
- **Table S7. Same as Table S5, but disaggregated at the biome level, showing the classification and description of soy properties according to compliance with legal reserve (LR) requirements (only Cerrado biome of Mato Grosso disaggregated) as referenced in the 'Results' section and 'Level of non-compliance with legal reserve requirements in properties with soy in Mato Grosso' subsection of the main text** doi: 10.12952/journal.elementa.000076.s011
- **Table S8. Properties with soy in the Amazon and the level of compliance with zero deforestation (soy moratorium) and the Forest Code as referenced in the 'Results' section and 'Soy Moratorium: effectiveness for zero deforestation but not for compliance with forest legislation' subsection of the main text** doi: 10.12952/journal.elementa.000076.s012
- **Table S9. Properties with soy in the Amazon and level of compliance with the soy moratorium and the Forest Code (same as Table S8), including areas of legal reserve surpluses and deficits as referenced in the 'Results' section and 'Soy Moratorium: effectiveness for zero deforestation but not for compliance with forest legislation' subsection of the main text** doi: 10.12952/journal.elementa.000076.s013
- **Figure S1. Summary of data processing and operations**
  This figure summarizes all processing and analytical operations conducted in order to obtain a final dataset with all needed information as described in the 'Methodology' section and 'Data processing' subsection of the main text. doi: 10.12952/journal.elementa.000076.s014
- **Figure S2. Framework to classify properties according to compliance with legal reserve (LR) requirements**
  This figure is a flowchart detailing how properties were classified as compliant or noncompliant according to Forest Code legal reserve regulations, considering the amnesty granted to small holders (up to four fiscal modules) by the current Forest Code version (2012). doi: 10.12952/journal.elementa.000076.s015

Data accessibility statement

The datasets used for this publication will be available on the following Google Drive accounts:

Combined PRODES/INPE (2014) for Amazon deforestation, SIAD/UFG (2014) and PMDBBS/IBAMA (2009) for Cerrado deforestation raster datasets: https://drive.google.com/file/d/0By5B2HyNqQ2lQ1ZtNzlVS3hacUU/view?usp=sharing

Combined land boundaries datasets spatially joined with soy map (Macedo et al., 2012): https://drive.google.com/file/d/0By5B2HyNqQ2lYnNDLU9wZlREcWs/view?usp=sharing