



From Amazon Pasture to the high street: deforestation and the Brazilian cattle Product Supply Chain

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Research Article

From Amazon pasture to the high street: deforestation and the Brazilian cattle product supply chain

Nathalie F. Walker^{1,*}, Sabrina A. Patel¹, Kemel A. B. Kalif²

¹ National Wildlife Federation, National Advocacy Center, 901 E St. NW, Suite 400, Washington, DC. 20004, USA.

² Amigos da Terra - Amazônia Brasileira, 44 Rua Cônego Roque Viggiano, São Paulo, Brazil.

*Corresponding author; email: walkern@nwf.org

Abstract

Brazil has the world's highest annual area of tropical deforestation, and cattle ranching is the largest driver of deforestation in the Brazilian Amazon. Recent domestic and international market demand for beef and leather that are not linked to deforestation led the largest Brazilian meatpackers to adopt policies to reject supplies from ranches with recent deforestation. However, increased and sustained enforcement of such policies will be needed to reduce deforestation in these supply chains over the long-term. We sought to map the Brazilian cattle product supply chain to determine the proportion of the market, and of cattle production, that may be susceptible to market demands for deforestation-free supplies. Beef, leather and live animal exports are the most valuable products from the cattle industry, with export values tripling between 2001 and 2009, and with China, Russia and the U.S. as the largest importing countries. The markets for dairy and tallow (beef fat) are predominantly domestic. We find that around 40% of beef and 85% of leather production serve markets that have expressed concerns over environmental impacts of their purchases, while the clandestine market, which is not susceptible to market environmental demands, is estimated to comprise about one quarter of the Brazilian cattle slaughter. Demand for Brazilian cattle products is growing, and while market-driven efforts to reduce deforestation linked to legal slaughter have shown success, improved governance and other measures will be needed to tackle the environmental impacts of the clandestine industry.

Keywords: *deforestation, Brazilian Amazon, cattle, leather, sustainable markets*

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Introduction

There is a growing awareness of the need to address deforestation in order to protect biodiversity and ecosystem services and reduce global greenhouse gas (GHG) emissions [1,2,3]. In order to effectively implement any plan to protect tropical forests, it is important to understand what is driving deforestation. In recent years, 48% of all tropical rainforest loss occurred in Brazil [4], where cattle ranching drives around three-quarters of forest clearing [5,6]. Between 2003-2008, greenhouse gas emissions from forest loss accounted for over 50% of Brazil's annual GHG emissions [5], which ranked it the world's third largest GHG emitter, after China and the U.S. [7].

Brazil has the world's largest commercial cattle herd, is the top exporter of beef [8], and is a major exporter of leather. Beef production for export is relatively new to the Amazon; until the mid-1990s, cattle supplied domestic markets and ranchers raised cattle to occupy the area for land speculation, establish tenure and secure government loans [9]. However, the domestic eradication of hoof-and-mouth disease, problems with "mad cow" disease outside of Brazil, and currency devaluation led to a rapid rise in exports over the past two decades [9,10]. The cattle industry also has social concerns, including bonded labor and land-grabbing [11], which are also of concern to the beef and leather industries.

Since 2009, steps have been taken towards reducing the impact of cattle-raising on deforestation. These followed the release of reports by the non-governmental organizations (NGOs) Greenpeace [12] and Amigos da Terra - Amazônia Brasileira [13], which demonstrated how major international meat and leather brands in the U.S. and Europe were selling products sourced from slaughterhouses supplied by ranches implicated in illegal deforestation, and how the Brazilian National Development Bank (BNDES) was the major funder of a rapid expansion of slaughterhouses in the Amazon. While ranching covers tens of millions of hectares of the Brazilian Amazon and there are hundreds of thousands of ranches, there are points of concentration. In 2009, four meatpackers (JBS, Bertin, Marfrig and Minerva) controlled a large proportion of slaughterhouse facilities and were responsible for producing over one-third of Brazil's beef exports [12].

Following the release of these NGO reports and legal action by the Public Prosecutor's Office in the Amazon state of Pará, key meatpackers and supermarket chains in Brazil and major international leather brands (35 companies in total [14]) announced new policies against deforestation in their supply chains. Meatpackers in Pará State signed an agreement with the Public Prosecutor's Office to buy only from ranchers registered with the Pará State Rural Environmental Registry (Cadastro Ambiental Rural, or CAR) [15,16]. On October 5th, 2009, the four meatpackers JBS, Bertin, Marfrig and Minerva signed an agreement with Greenpeace (the G4 Cattle Agreement, although Bertin was subsequently bought by JBS), also known as the "Cattle Moratorium" or "Cattle Agreement." The Cattle Agreement sets out a timeline by which these meatpackers would buy only from ranches in the Brazilian Amazon where no deforestation occurred after the date of the agreement [17].

The supply chain from ranch to slaughterhouse in the Amazon is complex, as many small ranches breed cattle and sell to fattening farms and other types of ranches that directly supply slaughterhouses. The meatpackers started to implement the Cattle Agreement by obtaining a geo-referenced location point from each of their direct supplying ranches and overlaying these points on maps of recent deforestation, protected areas and indigenous lands. Any supplier they found located close to such areas was then required to prove that the new deforestation was not on their property or they would be suspended from supplying the slaughterhouse. In July 2010, the meatpackers announced that they had suspended purchases from 221 ranches [18]. The next steps in implementing the Cattle Agreement were to obtain full global positioning system (GPS) boundary coordinates of all the directly supplying ranches (often large fattening farms), to subsequently address indirect suppliers (which are often small calving ranches), and ultimately to have the implementation of the Agreement independently audited [19]. Indirect suppliers are likely to present a much greater challenge than direct suppliers, because the ranches are usually smaller, are more numerous and are not in direct communication with slaughterhouses.

The leather industry has subsequently begun to link the efforts of slaughterhouses to their own supply chains through the international Leather Working Group [20]. This group was established to improve environmental standards in the leather industry; its members include major leather brands and tanneries such as Adidas, New Balance, Nine West, Puma and Nike [21]. In 2010, the Group agreed on new standards in a revised Tannery Auditing Protocol, which calls for leather sourced from the Amazon forest biome to be traceable to ranches with no post-October 2009 deforestation [22]. This protocol, along with zero deforestation policies of large supermarket groups, meant that many of the largest customers of the major meatpackers were asking for deforestation-free supplies.

The deforestation rate in the Brazilian Amazon fell by 14% between August 2009 and 2010 [23], possibly suggesting early signs of success with the Cattle Agreement. However, long-term progress in the face of forces that may encourage deforestation, such as agricultural commodity price rises [16] or a change in forest legislation [24], will require a concerted effort by the cattle industry to fully implement the Cattle Agreement, as well as similar undertakings by a greater proportion of the cattle product industry.

Commercial and export-oriented agriculture are increasingly supplanting smallholder agriculture as drivers of deforestation [10,25,26,27]. Commodities are transported across countries and continents by international trading companies to produce goods by international brands that are sold by multinational retail outlets. While international demand for products originating in tropical forest areas may drive expansion, it also presents opportunities to reduce deforestation as consumers and companies create pressure for “forest friendly” products [10,28]. Environmental NGO campaigns linking products sold by multinational corporations to deforestation have led to changes in corporate purchasing policies, supply chains and revised lending policies by financial institutions [29]. A key example of this is the Amazon “Soy Moratorium”. Following a Greenpeace report [30] connecting deforestation with soy exported to Europe and used in animal feed that was fed to chickens sold in major supermarket and restaurant groups, many of these companies demanded deforestation-free soy from their suppliers. This led the Brazilian Vegetable Oil Industry Association (whose members include the major soy traders) to agree not to purchase soy from newly deforested areas of the Brazilian Amazon [31]. The moratorium was agreed to in 2006 and an assessment in 2010 found soy cultivation on just 0.25% of post-moratorium deforestation in the Amazon forest biome [32].

In the past decade, awareness has grown among consumers, policymakers and financial institutions of the impacts of export-oriented agriculture on deforestation and resulting GHG emissions. Multinational companies have reacted by participating in multi-stakeholder processes to certify products which do not come from recently deforested areas (such as the Roundtables on Sustainable Palm Oil, Responsible Soy and Sustainable Biofuels), adopting policies to avoid sourcing products from recently deforested areas, tracing their products back to specific farms, and disclosing their exposure to forest risk commodities (by participating in the Forest Footprint Disclosure Project [33]).

In order to garner sustained and increased demand for deforestation-free cattle products among producers and users, these products need to be identified. Therefore, a key step is to map the cattle goods supply chain to determine the key products, companies and consumer markets [34]. It is also important to understand the nature and size of the ‘clandestine’, illegal market [35], which is unlikely to respond to market signals. We analyze and document the Brazilian cattle supply chain and the full range of cattle products and their markets, assess initiatives to produce deforestation-free products, and examine opportunities to leverage demand for such goods.

Our key questions are: (1) What is the range of products and where are the markets that the Brazilian cattle herd supplies? (2) What is the role of Brazil's Amazon cattle herd in deforestation and which products and markets are driving demand that is resulting in expansion of cattle in the Amazon? (3) What proportion of the cattle industry is most susceptible to market environmental demands, what proportion is unsusceptible, and what are the implications for Amazon forest conservation?

Methods

The Brazilian Amazon and Deforestation

Brazil's Amazon forest biome occupies 49% of Brazil's land area [36] but most production and export data are reported at the state and municipality levels. Therefore we used data for the Legal Amazon [37], which includes all of the states of Acre, Amapa, Amazonas, Mato Grosso, Pará, Rondônia, Roraima and Tocantins and part of Maranhão, covering a total area of about 5,217,423 km² or 61% of Brazil's land area. Deforestation data were obtained for the period 1994-2010 inclusive, using data from the Brazilian National Institute for Space Research [38].

Production and Export of Cattle Products

We used official Brazilian Government data from the Instituto Brasileiro de Geografia e Estatística (IBGE) to obtain numbers of cattle raised and slaughtered and the production of cattle products at the national and state levels. We used data from the Brazilian Ministério do Desenvolvimento Indústria e Comércio Exterior (MDIC), Secretaria do Comércio Exterior (SECEX) and the Association of Brazilian Beef Exporters (ABIEC) [39] to compare domestic Brazilian beef production and exports. We took statistics for cattle numbers and the production of beef and leather from the IBGE between the years of 1994 and 2009 and compared these with cattle product exports. In order to understand the importance of different markets for slaughterhouses, we assessed the relative value of key products (beef, leather and tallow) per head of cattle on the export market through a literature review of the average weight per animal of different products, and used data from MDIC for export values.

In order to compare imports and exports among countries, there is an international standard for coding products called the Harmonized System, or simply HS, which divides broad categories of products into two-digit codes with further details of up to ten digits. We used Brazilian government sources and the UN trade database, UN Comtrade [40], to obtain export and import data for a range of cattle products. For exports from Brazil, we used MDIC ten-digit HS code data, which provide the most detailed data for beef, leather and other cattle products. Export data are available in US dollar value or in kilograms (kg); when collating different products, we used the dollar value since we are concerned about the relative importance of the market or source of income. Global data for imports and exports are not available at the ten-digit HS code data level, and in the case of leather, this means that we were not able to distinguish between bovine and other sources of processed leather. Another weakness of available trade data is that collated values of leather products include shoes, purses and other products, the composition of which may be less than 50% leather. This makes it difficult to assess the proportion of hides that are exported (either as hides or finished products), so we reviewed available analyses of the Brazilian leather processing industry to obtain this figure. Despite these issues with the data, comparative values can still provide valuable insights into international trade in cattle products and where future market demand is likely to be most influential. When comparing the value and destinations of different types of beef products (fresh, frozen, canned) we used data from 2009 as the most recent year with representative data because in 2010, Brazilian processed beef was not exported to the U.S. for several months due to the discovery of unsafe levels of an anti-parasitic drug, which reduced exports of processed beef by over 50% [41,42].

Tallow

Tallow is processed beef fat (suet), which enables it to be stored and transported at room temperature [43]. Whereas there are official government production data for cattle and hides, there are no such official, national data for tallow. Domestic production of bovine tallow was estimated by taking the national average quantity produced per kilogram of beef by slaughter weight, and then multiplying this by the number of carcasses. The result, however, would be the production potential rather than the actual quantity produced.

Estimating the Size of the Clandestine Market

According to Brazilian Law Nº 7.889 of November 23, 1989, all meat production facilities that distribute meat across state or national borders must be inspected by the Brazilian Ministry of Agriculture, Cattle and Supply [44]. Meat distributed within states or municipalities must be inspected by state or municipal government. Facilities inspected have a Federal Inspection Service (SIF), State Inspection Service (SIE) or Municipal Inspection Service (SIM) code, and meat may be labeled with such a code. Any meat produced at facilities without official inspection codes (SIF, SIE or SIM) is considered to be part of the clandestine market [45]. We sought to estimate the size of this market.

Whereas government data on cattle slaughter come from figures at slaughterhouses, which are inspected and officially registered, these rules are in place to ensure hygiene standards are met. There are no such requirements for hides and therefore, the difference between number of animals legally slaughtered and number of hides produced can serve as a proxy for the size of the clandestine market. It is possible that some slaughterhouses may be under-reporting slaughter numbers (to reduce their taxes), but as this practice would also be illegal, we would consider it part of the clandestine industry (although carried out at legal facilities). Figures for the production of raw hides are collected at tanneries [46]. IBGE statistics for the number of hides acquired for tanning do not address the country of origin of hides. However, because of lack of storage ability, raw hides are not imported into Brazil [47], so the difference in animals slaughtered versus raw hides gives an estimate of the clandestine market [48]. We obtained such data for a seven and a half year time span (using the partial data available for the first six months of 2010). Because this difference does not include slaughters where the hides did not get processed, the resulting figures for the clandestine market are a minimum estimate.

Cattle Supply Chain from Ranch to Slaughterhouse

We analyzed the cattle supply chain from ranch to slaughterhouse, based on field trips to Mato Grosso, the Transamazônica highway and a slaughterhouse facility in Marabá in Pará state [49] and reviewed literature on systems of cattle raising in the Amazon. We provide details in the section labeled “Cattle Supply Chain from Ranch to Slaughterhouse” below.

Results*Cattle and Slaughterhouses in the Brazilian Amazon*

Brazil's non-Amazon cattle herd slightly declined from 1994-2009, but the number of cattle in the Legal Amazon more than doubled, and 37% of all Brazilian cattle were located in the Legal Amazon by 2009 (Fig. 1). There are 67 officially registered slaughterhouse facilities located in the Legal Amazon, 34 of which are licensed to export beef [50,51]. The exporting slaughterhouses are owned by a handful of meatpackers, over two-thirds of which have signed up to the Greenpeace Cattle Agreement [51].

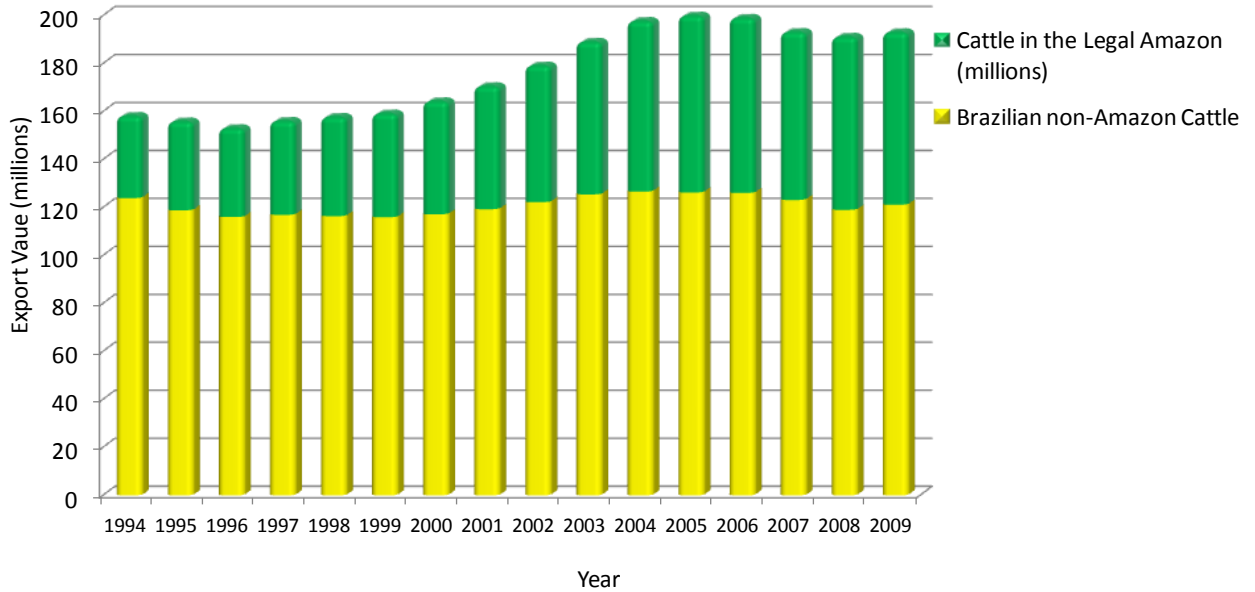


Fig. 1. The Brazilian Cattle Herd: Amazon and non-Amazon. Source: SIDRA (2011) [52].

The Amazon Cattle Product Supply Chain

While beef and leather are the primary and most valuable products, co-products made from the fat, bones, blood, hooves and horns all find their way into an enormous variety of products, from cosmetics to biofuels (Fig. 2). Most cattle originating in the Amazon are slaughtered in the region, but their meat, leather and co-products can be found on sale elsewhere in Brazil and are also exported all over the world [12,47]. Live animals are also exported from the Amazon for slaughter in a number of different countries and continents [47]. Figure 3 shows some of the major supply chains for cattle products originating in the Amazon; a more detailed analysis of export destinations is provided below.

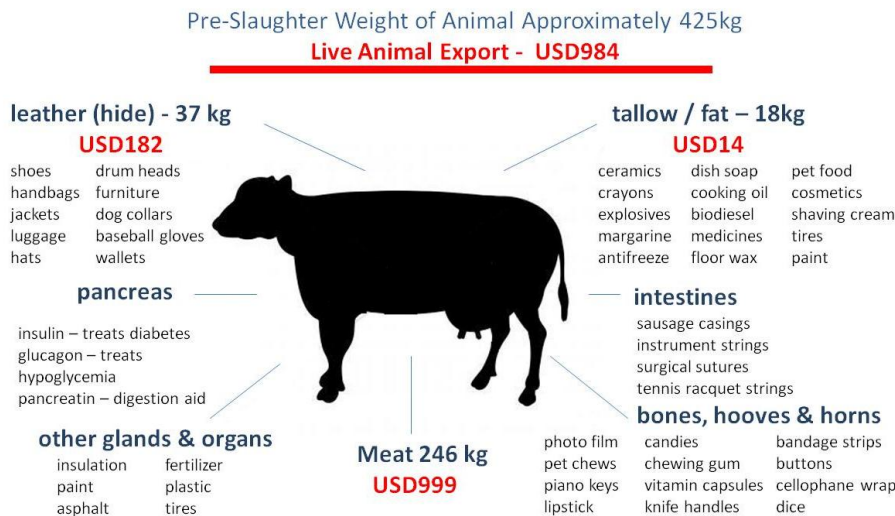


Fig. 2. Range of Products from Cattle, with Export Values per Animal. Figures (USD) are the Average Export Value for Each Product in 2010 (for further information see section “Cattle Values and Products section”.) Source: MDIC (2011) [46], California Department of Food and Agriculture (2011) [53], Oklahoma Cooperative Extension Service (2011) [54], Oregon Agriculture in the Classroom Foundation (2011) [55], Meat & Livestock Australia (2011) [56], PETA (2012) [57].

Cattle Products and Values

When cattle are purchased by a slaughterhouse, the price is determined by a formula called the “carcass yield,” which for Amazon cattle ranges from 51- 55%. The carcass consists of the meat and bones and does not include a payment for leather or other co-products [58]. These co-products are used in an extremely wide array of food, household and industrial goods (Fig. 2).

The average weight of an animal of the Nellore breed typical in the Amazon is 425kg, and carcass weight is approximately 246 kg [59]. The average export value of this meat, as fresh or frozen beef, was USD 4.06/kg in 2010 [60], making the average value of the beef in one head of cattle USD 999.

When considering leather, many slaughterhouses own tanneries and so the export value varies greatly, depending upon the level of processing. For 2010, the average hide export value (assuming an average hide weight of 37kg) was USD 182 per animal [47]. For tallow, the average extraction per animal is 18kg [61]. The export market value of tallow in 2010 averaged USD 0.76/kg [62], making a head of cattle yield approximately USD 14 of tallow.



Fig. 3. Overview of Cattle Supply Chain –Leather, Beef, Live Cattle and Co-Products. Source: COMTRADE 2011 [40]; SIDRA 2011 [52]

Export Markets for Cattle Products

Between 2006 and 2010, beef accounted for around two-thirds of the export value of Brazilian cattle products, leather was responsible for over one-quarter of the export value, and live animals made up around five percent of the export value (Fig. 4).

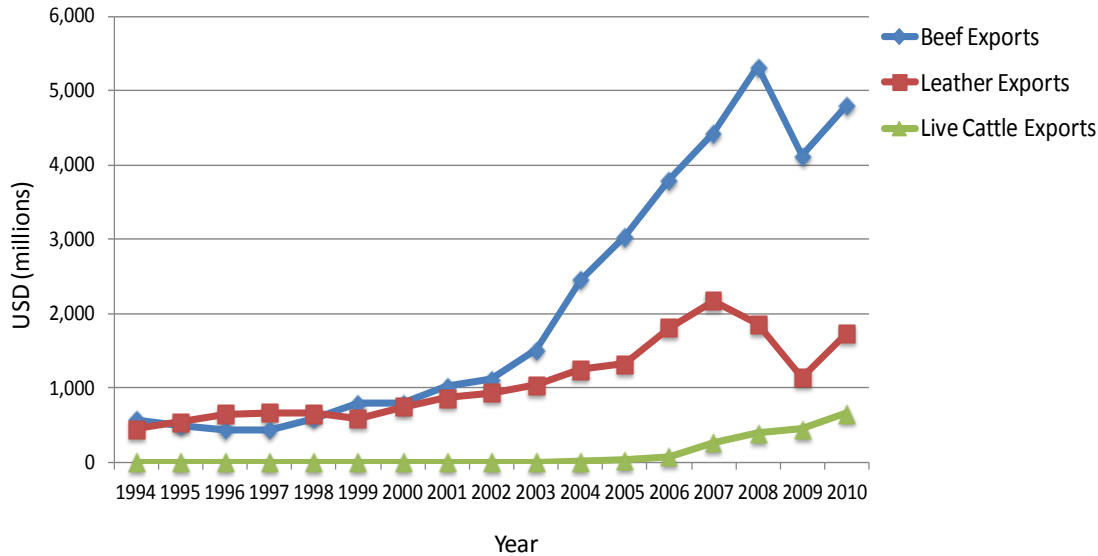


Fig. 4. Exports of Brazilian Beef, Leather and Live Cattle 1994-2010. Source: MDIC (2011) [47].

These products have all seen export growth from 1994 to 2009, and their total value tripled between 2001 and 2009 (Fig. 4). Other co-products, such as tallow, have seen similar increases, but the total value of their exports is far smaller than the key three product types in Figure 4. This growth occurred during a period of rapid expansion of the Amazon cattle herd, while the rest of the country’s herd size did not increase (Fig. 5). The impact of growing export markets on cattle production in the Amazon may have been indirect as well as direct (in all sectors apart from live animal exports, the majority of exports are of products originating outside of the Amazon).

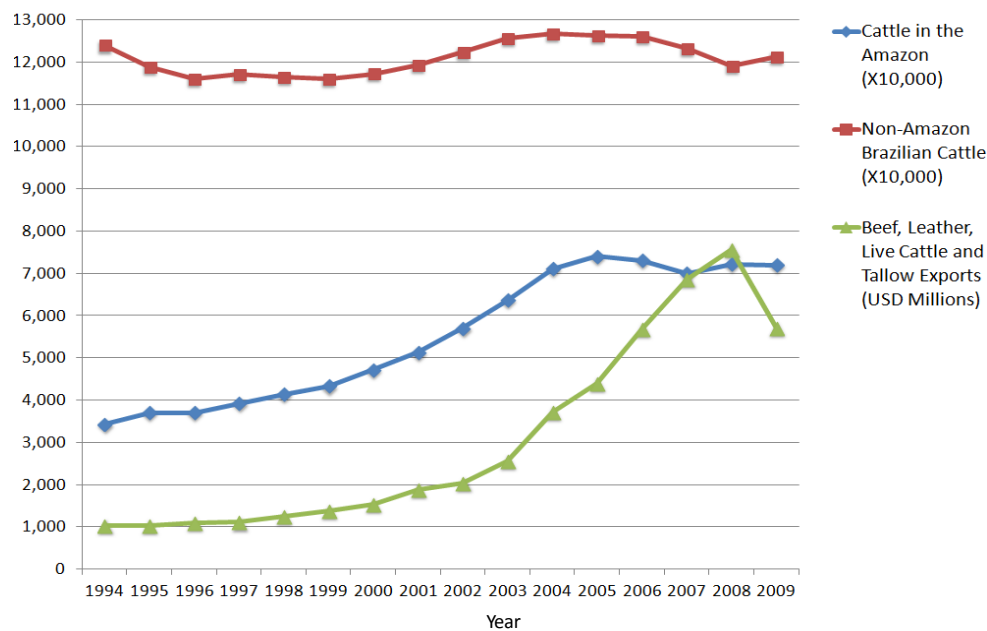


Fig. 5. Brazilian Beef and Leather Exports and Herd Size. Source: MDIC (2011) [47], SIDRA (2011) [52].

Beef Production and Export

Brazil's beef export market has rapidly expanded in recent decades, making Brazil the world's biggest beef exporter [40]. While domestic consumption of beef increased almost 50% between 1994-2009, exports tripled, and between 2005 and 2009, 24% of beef was exported (Figure 6) averaging around USD 4 billion in value [47]. The major export destinations for all beef products (fresh, frozen and processed) were Russia, China, Iran and the United States, with over half of exports going to the Middle East and Asia (Fig. 6). However, considering processed beef, 69% of exports by value went to the U.S., U.K., Italy and the Netherlands, the top destination being the U.S., which in 2009 received 34% of Brazil's processed meat exports [60]. Of all types of beef, in 2009, 20% of exports by value were destined for the E.U. and the U.S., with a combined value of USD 840 million, which represents 4% of total Brazilian beef production by weight [60].

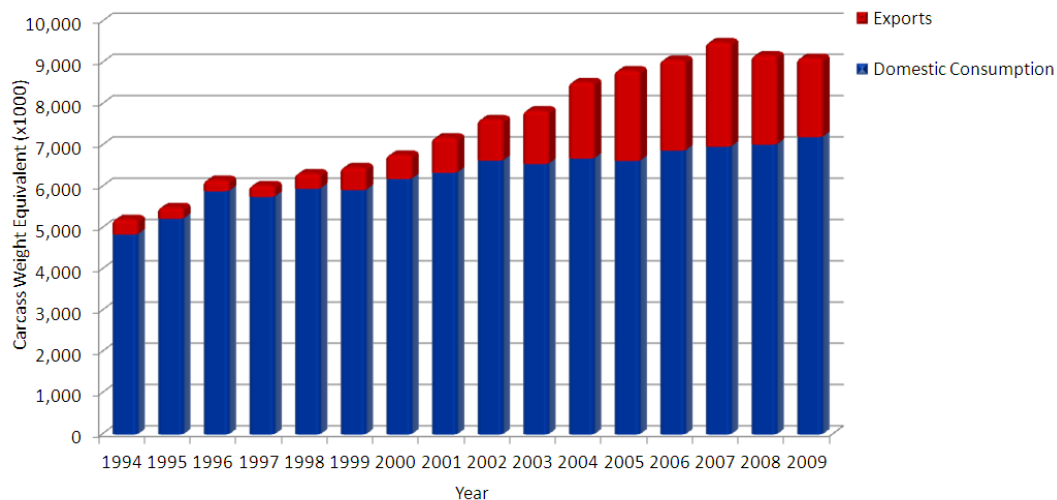


Fig. 6. Brazilian Beef Domestic Consumption versus Exports (Carcass Weight Equivalent X1000). Source: MDIC (2011) [47], SIDRA (2011) [52].

Leather Production and Exports

Brazil's leather export supply chain is complex, because a wide variety of leather products and types are exported. The majority of exports are of 'wet blue', chrome-tanned hides, but Brazil is also a major producer and exporter of shoes and other leather goods. The primary export destinations for Brazilian leather (by value) are China and Italy (Fig. 7), which are key manufacturing and exporting countries of leather shoes and bags. When leather is referred to as "Italian leather," for example, this indicates that the leather product was manufactured in Italy, but the hide could have originated from another country.

Analysis of international trade in hides and processed leather (such as footwear and accessories) from 2006-2010 found that while around half of Brazil's hide exports went to China and Italy, the U.S. was the largest importer of Brazilian processed leather, which includes products such as footwear and purses (45% by value, 56% by volume) [40]. Brazil is the largest source of hides for Italy and second greatest source for China (behind the U.S.), accounting for 13% and 9% of all imports respectively [40]. Italy and China are the top global leather processors, and both export the bulk of the leather they produce; 11% of Italy's processed leather exports by value go to the U.S., while 45% of China's leather exports are destined for the U.S. [40].

Considering combined leather products directly exported from Brazil, and those that reach the U.S. via processing in China and Italy, the U.S. is the major export market for Brazilian leather [9,40]. However, it is not possible to

accurately calculate the percentage of Brazilian leather production destined for the U.S. because of the limitations of the HS code reporting system. This is because shoes differ widely in their percentage composition of leather, there are discrepancies in reporting between Chinese exports and U.S. imports [62], and while import and export figures for China are available, the percentage of Chinese leather used that is sourced from Chinese cattle is not available. However, this number is probably very low, as foreign-owned tanneries in China (pers. comm. March 26th 2010) have indicated that all of their hides are imports.

In order to assess the proportion of all leather production exported (hides, finished products and all products in between) from Brazil, we used data for hides (in animal unit equivalents) exported, hides processed domestically whose finished goods were sold domestically, and those processed domestically but whose finished goods were subsequently exported, for the year 2008 [63]. The resulting figure is that a total of 74% of Brazilian leather was exported in 2008, which includes the proportion of leather finished in Brazil that was subsequently exported (40%) [63]. We used a data source that included the proportion of leather finished in Brazil which was subsequently exported, but it is similar to other assessments, such as by the Center for the Brazilian Tanning Industry (Centro das Industrias de Curtumes do Brasil) [64].



Fig. 7. Export Destinations of Brazilian Beef, Leather and Live Cattle in 2009. Source: MDIC (2011) [47].

Tallow and Other Co-Products

One of the most widely recognized uses of animal fat, particularly beef tallow, is the soap industry, which creates products ranging from personal hygiene to industrial detergents. Tallow is also used in the production of rubber and plastic [65] (Fig. 2). Animal fat is also an important source for the production of biodiesel in Brazil (which constitutes 10-20% of all biodiesel production in recent years), second only to soy oil for this purpose [66]. Our estimate of production potential of animal fat for Brazil in 2010 is 947,878 Mt, which is similar in magnitude to an estimate of 740,000 Mt/year provided by Zoé Morés of the Brazilian Association of Industrial Soaps (Associação Brasileira das Indústrias Saboeriras e Afins) (pers. comm. November 19th 2010). The lower estimate has a total value (based on the average export price in 2010) of USD 564,000 [47] but in 2010, less than 1% of estimated production was exported [47].

Live Exports

While beef exports originating from the Legal Amazon account for just over a quarter of Brazil's total exports, the Amazon state of Pará alone is responsible for over 90% of Brazil's live cattle exports [47]. Lebanon and Venezuela are the major export destinations (Fig. 7). The number of Brazilian live exports surpassed 500,000 animals in 2010 [47], with a value of around half a billion USD.

Dairy Production

Currently, Brazil has approximately 1.2 million dairy farms across the country, almost two-thirds of them concentrated in the centre-south of the country [67]. We have not included dairy in our analysis of the cattle value chain because of difficulties in obtaining data about the Amazon industry, in part due to the market being more localized and domestically focused.

The Clandestine Slaughter Industry

The clandestine market in Brazil consists of slaughterhouses which are illegal and not registered with the government. By comparing the total number of hides produced with the number of reported slaughters, the cattle slaughtered by the clandestine market can be estimated [48] (Fig. 8).

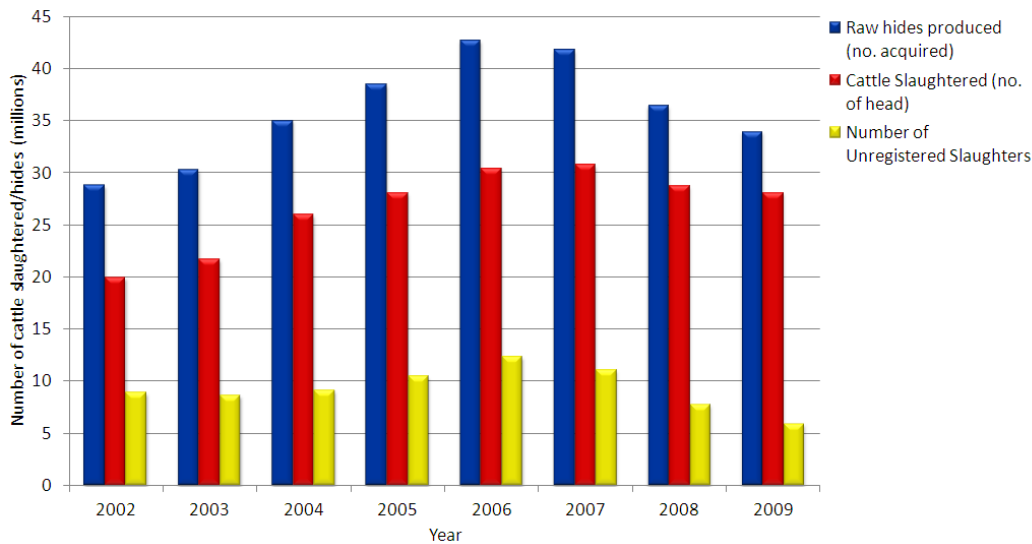


Fig. 8. Estimates of the Number of Cattle Slaughtered by the Clandestine Cattle Industry. Source: SIDRA (2011) [52].

Figure 8 shows that the percentage difference between the number of hides and the number of slaughters decreased from 44% in 2002 to 21% in 2009. In 2009, the year demonstrating the lowest percentage in the series, leather tanneries purchased almost 6 million hides that could not be attributed to a cattle slaughter, and on average from 2002-2009, 26% of all slaughters were clandestine. The average monthly difference over the six months of 2010 that were accounted for remained at around half a million hides from unregistered slaughters, with a 21% difference between the number of head of cattle slaughtered and number of hides registered [52].

Cattle Supply Chain from Ranch to Slaughterhouse

The Brazilian Amazon contains a variety of types and sizes of producers, including those ranches that supply cattle directly, calving ranches, and intermediary ranches (indirect suppliers). Cattle may also pass through auctions before reaching a slaughterhouse (Fig. 9). Calving ranches are often small properties, while fattening farms (which buy cattle from smaller producers and raise them until they reach a weight suitable for slaughter) are often thousands of hectares in size and sell thousands of cattle per year to slaughterhouses. In the Amazon, most cattle are raised on pasture and are grass-fed [49]. Although there are some feedlots where cattle are reared on grains rather than grass for either the entire year or just during the dry season, this practice is not common but is growing, having been introduced, for example, to Pará state only in 2007 [68]. While this whole

picture complicates traceability from finished products back to ranches, it is possible to track cattle origins by making use of the requirement for vaccination certificates for transporting animals (called an animal transit guide *Guia de Transporte Animal* (GTA)). In 2009, the federal Ministry of Agriculture piloted a program, *Boi Guardião*, or Cattle Guardian, whereby ranchers with deforestation could not obtain GTAs [69].

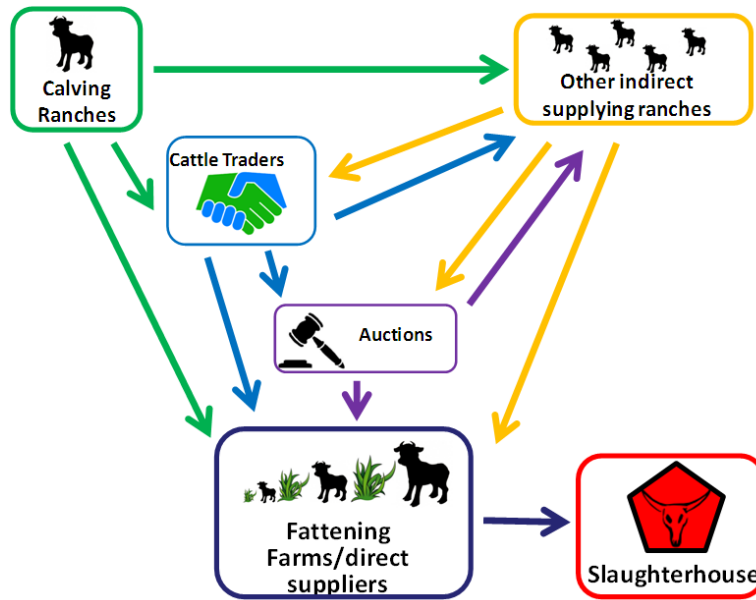


Fig. 9. The Amazon Cattle Supply Chain from Ranch to Slaughterhouse. Source: Kalif [50].

Cattle and Deforestation

Deforestation in the Legal Amazon rose sharply from 2001-2005 but then even more rapidly declined to less than a quarter of the 2004 peak (Fig. 10). In Mato Grosso, the state with the largest cattle herd, 2010 deforestation was reduced to just 7% of the 2004 peak [38].



Fig. 10. Deforestation in the Brazilian Amazon. Source INPE (2011) [38].

DeFries *et al.* (2008) [70] calculated the number and size of deforestation events in Mato Grosso from 2001-2005 (Fig. 11). While 68% of deforestation events were of less than 25 hectares in size, they accounted for only 13% of the total area deforested, whereas 66% of area deforested occurred through deforestation events greater than 100 hectares.

Macedo *et al.* (2012) [26] assessed post-clearing land use in Mato Grosso of deforestation events larger than 25 hectares. In 2001-2005, most deforestation in Amazonia occurred in large clearings. Since 2005, deforestation rates have declined in Mato Grosso and other Amazon states, and the relative importance of small clearings (<25 ha) has increased. The use of these small clearings for cropland, pasture, or other agricultural uses is more difficult to determine using satellite data time series [26]. Macedo *et al.* (2012) [26] attribute the decline in deforestation for cropland, and the overall decline in large-scale deforestation in Mato Grosso, to a combination of government policies and industry-led initiatives to reduce deforestation.

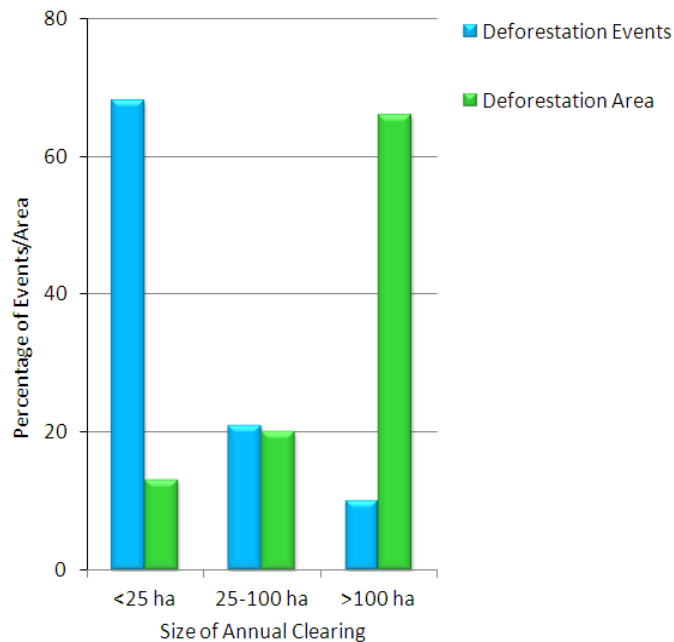


Fig. 11. Number and Size of Deforestation Events in Mato Grosso (2001-2005). Adapted from DeFries *et al.* (2008) [70].

Discussion

Agricultural Development in the Brazilian Amazon

For much of the 20th Century, agricultural development in the Brazilian Amazon was hindered by high rainfall and acidic, infertile soils, as well as by dense forest [71], and therefore, extractive activities were the major industries in the region. When Brazil came under military rule in 1964, the government adopted a production model that incentivized the establishment of large private companies in the Amazon and the use of mechanization and chemicals for agriculture, as well as provided financing for forest clearing as a means of demonstrating land tenure [72,73]. This led to a large increase in deforestation; the total area land cleared in the state of Mato Grosso increased from 920,000 hectares in 1975 to six million hectares by 1983 [74].

Another factor contributing to the rise in deforestation was land speculation. The main source of income for farmers was the sale of cleared land [75], especially in regions or during periods where land prices rose faster than inflation. Under these conditions, the cheapest way to secure the possession of cleared land until it was sold, was to raise cattle as "proof" that the land was in use. This logic still exists today, where a hectare of forest has a cheaper sale value than a hectare of cleared land [76].

In the last decade, there has been a large increase in both cattle in the Brazilian Amazon and exports of all key cattle products. Expansion of the cattle industry has been the major driver of deforestation in Brazil for many years [16], and export markets have become an increasingly important source of demand for the growth in Brazil's cattle industry. The dominant role of commercial and export-oriented agriculture in deforestation is a pattern that has been seen across the tropics [25]. Gibbs *et al.* (2010) [77] analyzed the Landsat satellite database to determine land cover change across the tropics during the 1980s and 1990s and found that over half of new agricultural land had come from intact forest and an additional quarter was from land that had been disturbed (forests that had been subject to logging or other forms of degradation). In South America, in the 1990s ten percent more agricultural land was found to have come from rainforests than in the 1980s, showing deforestation for agriculture to be an increasing threat to forests in the region. With exports of Brazilian beef projected to rise 80% in the next ten years [78], exports will become increasingly important in shaping the future rate of deforestation driven by cattle.

The Cattle Value Chain and Action to Reduce Deforestation

As the Amazon cattle industry has grown in recent years, there has been a concentration of the market in which a few large meatpackers have expanded their operations in the Amazon, the major funder being BNDES [13]. The top two Brazilian meatpackers [51], JBS and Marfrig Group, have a global presence and are the first and third largest animal protein producers in the world, respectively. One half of registered slaughterhouses in the Amazon have export licenses and two-thirds of these have zero deforestation policies. If exports rise as predicted, the slaughterhouses with zero deforestation policies may gain a much larger share of the Amazon cattle market, or if other slaughterhouse facilities increase exports, international market pressure could help to encourage these companies to follow suit with similar policies.

While there is a demand for certified and deforestation-free products in the domestic market in Brazil [79], international media attention and consumer and corporate demand for "deforestation-free" products deforestation (particularly in Europe and the U.S.) played an important role in bringing about the Cattle Agreement and soy moratorium [80, 81]. The largest direct export markets for all products combined by value, are, in decreasing order, China, Russia, the U.S., Italy, Venezuela and Iran [47]. When direct and indirect exports are considered, the U.S. is the largest importer of leather products originating in Brazil. The E.U. is also an important market. In a recent survey, 35% of consumers in the U.S. stated that they were prepared to pay a premium for 'environmentally sustainable' products [82]. Greater awareness of the importance of U.S. markets to the Brazilian cattle industry could help to support the implementation of zero deforestation policies of meatpackers and U.S. companies selling meat and leather products.

While beef and leather, followed by hides, make up the bulk of the value that slaughterhouses get from cattle slaughter, there are also a wide variety of co-products. The price paid for cattle depends upon an animal's weight, and some ranchers have complained that they get money for the beef but are not compensated for hides or other co-products [58]. The meatpackers claim that the use of co-products of cattle slaughter is factored into the price they pay ranchers, but the cost paid to ranchers is not affected by, for example, whether the animal's leather has been marked or is in poor condition. According to a study by Scot Consultoria (2011) [83], reductions in the market price of cattle co-products, especially of raw leather and tallow, reduce the income of slaughterhouses, because payments for cattle by slaughterhouses are affected solely by beef prices. Therefore, while smaller in value, co-products could be an important profit generator for meatpackers.

Concerns over deforestation for cattle by Brazilian civil society have been focused on beef as the key driving force of the industry, as media stories have largely ignored co-products. The lack of official data on the domestic production of beef tallow hinders an effective analysis of this sector. However, this would not need to prevent support for a more sustainable cattle industry by companies using tallow. Whereas several beef and leather companies have adopted zero deforestation policies, there has not been similar action by the tallow industry to date. The domestic market dominates the use of beef tallow, specifically the cosmetics and personal care products industries. According to Reporter Brasil (2009) [84], just two companies, Colgate and Gessy, consume about 35% of the total domestic production. The use of tallow in biodiesel production in Brazil is also growing. The rate of use varies monthly, as it is a substitute for soy-based biofuels [85]. When soybean prices rise, there is a greater use of beef tallow. However, despite having a lower price than soy, the use of tallow in biodiesel appears limited by its technical qualities, because industrial plants are optimized for using vegetable oils. Biodiesel companies often state that they are environmentally responsible (by producing renewable fuels), but without implementing a system of traceability or purchasing requirements for the origin of beef tallow, they could be directly contributing to both deforestation and the clandestine slaughter of cattle.

Assessment of Proportion of the Cattle Industry that is and is not Susceptible to Market Environmental Demands

The direct suppliers of slaughterhouses are often large fattening farms, but their cattle may have been born on calving ranches (which are often small) and have passed through traders or auctions. While the GTA system does provide a means by which the properties cattle have been raised on can be traced, there is not yet a fully operational Amazon-wide system of traceability that also monitors deforestation on each property. The very low level of legal compliance and lack of secure tenure on many ranches are barriers to effecting change [11]. While the meatpackers signed onto the Cattle Agreement have taken steps to implement their commitment to ensure that their direct suppliers are complying with their zero deforestation goals, the complexity of the pre-slaughterhouse supply chain and the large number of ranches that can supply each direct supplier, make this stage far more difficult.

Given that the majority of deforestation in Brazil occurs on a large scale and on land subsequently used for cattle [26], focusing on direct suppliers to slaughterhouses constitutes a reasonable start in tackling deforestation. However, meatpackers in the Cattle Agreement control only about one-third of Amazon exports [12] and national slaughter [86]. The remaining two-thirds of the industry include legal and illegal slaughterhouses, which similarly service both national and international markets. Consumer concerns for the environment might eventually be brought to bear to influence these industry actors as well. Increased awareness of links not only to deforestation, but that at about one quarter of cattle slaughtered are part of the clandestine industry, could increase pressure for systems of traceability and more responsible practices.

Consumers and companies in the E.U. and U.S. have demonstrated concern about Amazon deforestation [80, 81]. These regions make up the largest markets for Brazilian leather goods, including both those which are exported directly and those which are processed via Asia. Therefore, all leather exports could be considered to be susceptible to demand for deforestation-free products. The U.S. and E.U. also import 4% of Brazilian beef. Eighty percent of Brazilian beef production is consumed domestically, as are the vast majority of co-products (excluding leather)[47]. Therefore, consumer concern in Brazil over deforestation related to the cattle industry is vital for sustained and increased action in the industry to reduce deforestation. A 2010 survey of Brazilian consumers found that 44% were concerned about the environment [79]. Overall, about 40% of beef and 85% of leather production serve markets potentially susceptible to concerns about deforestation.

Live animal exports to Venezuela have increased as cattle production in that country has decreased, and the government of Pará state has a commitment to a trade partnership with Venezuela for a range of agricultural products [87]. Exporting is attractive because prices paid for sale to Venezuela are higher than on the domestic market in Brazil [88]. Transport of live animals has been criticized by animal rights groups who have campaigned to ban it [89], but the market continues to grow, suggesting that it may be similarly unsusceptible to any environmental campaigns over deforestation. While this market is lucrative, the numbers involved each year, about one-half million animals, are equivalent to the estimated clandestine slaughter for only one month.

The clandestine slaughter industry is, by definition, another sector which is unlikely to respond to market demand. Given its illegal nature, it is not possible to determine whether the average size, herd density of ranches or level of deforestation on ranches supplying clandestine slaughterhouses differ from the legal supplying ranches. Our estimate of 26% of slaughters in Brazil being part of the clandestine industry is similar to figures of illegal production in the dairy industry, where 20% of dairy production is estimated to be neither controlled, nor inspected [67]. However, some believe that the proportion of the market that is clandestine is much higher, and since we are only estimating clandestine slaughters whose hides are tanned, the actual size could be considerably higher. Variations in estimates could also be due to differing definitions of illegality and difficulties in obtaining data about an illegal market, but in the state of Mato Grosso, 50% of slaughter has been estimated to be illegal [90].

Sustainable Growth of the Cattle Industry

A number of multi-stakeholder initiatives have brought together the cattle supply chain and civil society to address concerns about deforestation. In addition to the aforementioned Cattle Agreement and the Leather Working Group, other initiatives include the Brazilian Working Group on Sustainable Beef (Grupo de Trabalho da Pecuária Sustentável) [91] and the Sustainable Agriculture Network's Cattle Standards, which were agreed to in 2010 [92].

In addition to market efforts to curb deforestation for cattle, progress in governance, finance and productivity methods have the potential to work together to steer the industry towards growth without deforestation. Since 2009, thousands of ranches have registered with the CAR [17], and improved enforcement of state and national law is increasing the pressure on meatpackers to increase monitoring of their cattle purchases [93]. Reducing deforestation is an integral part of the Brazilian Federal Government's GHG emissions reductions goals, which includes a deforestation reduction target of 80% by 2020 (which it predicted in 2010, could be met by 2016) [94].

The average stocking rate of cattle in the Legal Amazon rose from 0.3 to 0.9 animals per hectare between 1975 and 2006 [95]. While today the average stocking rate for cattle remains around one head per hectare, methods to at least double the number of animals per hectare (to over 2 animals/ha), based on improved pasture management techniques, have been developed and piloted by Brazil's Agricultural Research Agency, Embrapa [96]. If implemented, Brazil could reach its target for growth in production (and exports) through increasing herd size in the Amazon, without the need for any additional land clearance.

Since 2009, BNDES has revised its environmental guidelines for loans, requiring the adoption of traceability by the slaughterhouses to avoid purchasing cattle produced in areas of illegal deforestation or from ranches with forced labor, as well as requiring independent audits [97]. Other banks active in the agricultural sector have also adopted policies against lending to producers with recent deforestation on their properties [98].

Summary of findings to answer the three questions presented in this paper:

(1) What is the range of products and where are the markets that the Brazilian cattle herd supplies? The key products for Brazilian cattle are beef, leather, live animals and tallow. The vast majority of tallow and over three-quarters of beef is consumed domestically, but three-quarters of Brazil's leather is exported, and exports of beef and leather are growing. China, Russia and the U.S. are the largest importers (by value) of Brazilian cattle products.

(2) What is the role of Brazil's Amazon cattle herd on deforestation and what products and markets are driving demand that is resulting in expansion of cattle in the Amazon? Around three-quarters of deforestation in the Brazilian Amazon is driven by cattle expansion. While beef is the highest value product from cattle, leather and tallow provide important sources of income for meatpackers. Exports have risen steeply in recent years and are projected to be the largest growth area, so future expansion of the industry would be projected to be most influenced by exports.

(3) What proportion of the cattle industry is most susceptible to market environmental demands, what proportion is unsusceptible and what are the implications for Amazon forest conservation? About one-quarter of the cattle industry is not slaughtered legally and so is not susceptible to market environmental demands. Around one-third of the industry has already taken action as a result of market environmental concerns. As exports rise, with greater consumer and corporate awareness of the cattle supply chain and improved forest governance, the remaining proportion of the cattle industry may be more likely to take action to reduce deforestation in its supply chain. Implications for conservation are considered below.

Implications for conservation

In the past decade, around three-quarters of deforestation in the Brazilian Amazon has been driven by expansion of cattle ranching. Since 2009, market demands have led a significant section of the meatpacking industry to adopt zero deforestation policies that extend beyond legal requirements. While a comprehensive, independent auditing system is needed to ensure that these meatpackers are not purchasing cattle from ranches with recent deforestation, and addressing indirect suppliers will likely pose a much greater challenge, effective implementation by the major meatpackers has the potential to make one-third of the cattle industry deforestation-free.

Around one-quarter of cattle slaughter (driven by the clandestine industry) is unlikely to respond to market pressure. Regarding the remaining proportion of the Brazilian cattle industry, around 40% of beef and 85% of leather production may be influenced by consumer demand for deforestation-free products. Greater and sustained action from government, financial institutions and markets, together with increasing productivity through improved pasture management, could work collectively to reduce deforestation. Larger ranches that supply slaughterhouses directly are more likely to respond to such action than smaller, indirect suppliers. Therefore, if deforestation rates decrease, starting with large properties, then a rising proportion of remaining deforestation will likely be attributable to the small ranches.

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