

COMMENTARY

Will intensification of beef production deliver conservation outcomes in the Brazilian Amazon?

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The intensification of beef production has become a conservation target based on the idea of land sparing and the assumption that in order to contain deforestation and meet increasing beef demand we must increase productivity. There is also increasing attention and conservation credit being given to supply chain management in beef production. Based on a historical comparison between the US, a fully intensive system, and Brazil, one moving in that direction, we suggest that cattle ranching will intensify as a result of conservation investments (reductions in capital and land subsidies) rather than intensifying in order to produce conservation results. If the comparison holds, the new intensive system, however, will continue to require large natural resource inputs, government subsidies, and be plagued by social and conservation problems. It will also be held in thrall by a few large processing companies, which exert undue influence over both producers and consumers. Therefore, we suggest that closer attention be paid to attribution in the claim of conservation outcomes from intensive beef production.

Keywords: intensification; beef; deforestation**Introduction**

Cattle ranching in Brazil is commonly referred to as a driver of deforestation, which implies some degree of causality (Mertens et al., 2002; Margulis, 2004; Bustamante et al., 2012, among many others). This narrative has, in part, led to the recent and growing claims for the 'sustainable' intensification of beef production to serve as a conservation tool (Walker et al., 2010; Cohn et al., 2014; Strassburg et al., 2014; Marcuzzo & de Lima, 2015). The idea is based on the concept of land sparing, which in this case suggests that producing more beef on less land will slow deforestation and release pasture for additional crops. In addition, there is also increasing conservation credit given to supply chain management through 'cattle agreements' with major beef processing companies (Nepstad et al., 2013; Nepstad et al., 2014; Gibbs et al., 2016) and roundtable forums such as the Global Roundtable for Sustainable Beef (<http://www.grsbeef.org>).

The relationship between beef production and deforestation, however, is not easily defined, and it is possible that the conservation claims for sustainable intensification fall into the trap of focusing on proximate causes rather than underlying driving forces (Geist and

Lambin, 2002). It also possible that they miss key points about the beef industry that are already facilitating regional intensification: the readily available improvements in production and technology; the influence of the highly concentrated processing sector; the economics of the beef supply chain; government development objectives; and competition in the protein markets, among others. Furthermore, cattle ranching on the Amazon landscape is often attributed to three overarching themes: ranching is the least expensive means of establishing land tenure (Araujo et al., 2009; Bowman et al., 2012; Pacheco and Pocard-Chapuis, 2012); pasture expansion is a result of development incentives including tax breaks, settlement programs and subsidized credit, among other policies (Browder, 1988; Binswanger, 1991; Schmink and Wood, 1992; Hecht, 1993; Almeida and Uhl, 1995; Chaddad and Jank, 2006); and finally, that markets drive the increase in demand for beef and therefore ranching (Faminow, 1997). The first two themes can be described as institutional failures, whereby the quantity of beef supplied is influenced by exogenous policies or extra-sectoral government choices. These institutional failures muddy the links between the beef supply and deforestation, bringing market-based solutions into question.

Indeed, there is little to suggest that the reduction in deforestation from 2004 onward was due to anything beyond government policy and action, coming mainly in the form of: increased protected areas (Soares-Filho et al., 2010; Pfaff et al., 2013; Pfaff et al., 2015; Moutinho et al., 2016); withholding government credit to municipalities with high deforestation rates (Arima et al., 2014; Cisneros

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et al., 2015); technological advances in monitoring (e.g., Fonseca et al., 2015; INPE, 2016); and more efficient enforcement (Börner et al., 2014).

Here we explore the possibility that seeking positive conservation outcomes by increasing beef productivity and engaging directly with the supply chain may be a flawed approach and that the opposite could be true—i.e., conservation outcomes such as removing land from production, better oversight of land use, or improved enforcement will further catalyze intensification. Indeed, we seek to open the discussion that rather than being a driver of deforestation, it is possible that ranching is merely a companion to, and consequence of, overall land use decisions and part of a much larger development process that includes industrial actors and government policies.

To illuminate this discussion, we compare the history and current production conditions in the beef industries of Brazil and the U.S. We show that the U.S. beef sector, which produces a similar product, shares some hypothetical similarities to Brazil, but has intensified simply through competition for both land and market share. If conditions are broadly similar in Brazil, one could expect the industry to advance intensification as quickly as possible, regardless of conservation outcomes. Indeed, previous studies have shown similar cycles between the U.S. cattle industry and other South American herds (Mundlak and Huang, 1996). Any resemblance presented herein is not intended as definitive proof of future production trends, but rather to provide a useful comparison that can improve the debate surrounding ranching and deforestation. This article uses a literature review of the U.S. beef industry to establish its case and builds on several years of formal and informal engagement with the ranching sector in Brazil by the authors, including a recent cost benefit analysis of ranching (Barbosa et al., 2015), extensive field work in

development of models of the cattle sector (Bowman et al., 2012), and work in conjunction with local non-profits, such as Aliança da Terra (www.aliancadaterra.org).

The intensive beef industry of the U.S.

The first cattle herds to arrive in the U.S. were walked into Texas, then part of Mexico, during the 1540s and continued to trickle in for the next 300 years. Many of these animals wandered off—there were no fences and barbed wire was not invented until 1867—or were abandoned, and by end of the U.S. Civil War (1865) there were approximately five million head of longhorn cattle roaming free (Gard, 1954). The cowboy trade began with the collection of these feral herds and the trailing of cattle from the southern plains to northern markets, which continued until about the 1920s (Dale, 1960). There was also a bustling trade in the Midwest and East Coast where the British breeds began to arrive around the late 18th and early 19th centuries. The two breeds that eventually came to dominate the industry were Hereford, first imported into Kentucky in 1817,¹ and Angus in 1873.² As people migrated westward between the 1860s and 1930s, they brought their cattle with them and the mixing of the two major herds has continued ever since. By the time the frontier was declared closed in 1892, the U.S. had settled 1.5 million families on 108 million ha through the Homestead Act. The closing of the frontier did not, by itself, stop the migration of people westward, but rather stopped formal government support of that process. Once the population attained a given density, an era of increasing land scarcity began.

The U.S. herd increased from 38 million head in 1876 to a peak of around 130 million in 1976. Today a herd of approximately 89 million (**Table 1**) is spread throughout the U.S. This is roughly a 30% decline in population over a period of 40 years. **Figure 1** shows the distribution of

Table 1: U.S. and Brazil beef industry production statistics. DOI: <https://doi.org/10.1525/elementa.224.t1>

Item	Unit	Brazil	U.S.
Total herd	Million	216 ^a	89 ^e
Beef cows	Million	48 ^a	29 ^e
Slaughter	Million	44 ^a	32 ^e
Volume beef production	Million tons	8.4 ^b	11.7 ^e
Value beef production	Billion US\$ ^c	27 ^d	88 ^e
Percent finished in feedlots	%	11 ^g	>90 ^f
Processing company concentration	%	43 ^h	80
Range/pasture area	Million ha	220	270

^a IBGE (2014) data,

^b Instituto FNP (2013),

^c 1 US\$ = R\$ 2.1,

^d MAPA (2014b),

^e USDA (2014a),

^f USDA (2014b),

^g Barbosa et al. (2015),

^h Macedo & Lima (2012); concentration is defined by percent of market share in processing by the 4 largest companies.

the cow-calf herd in the U.S. and Brazil—herd density in each is approximately 12.6 head per km² in the U.S.³ and 25.7 per km² in Brazil. According to the most recent farm census, there are more than 700,000 farms (29% of all the farms in the U.S.) specializing in cattle;⁴ more that 90% of

these farms have herds of less than 100 cows (the average is 44), making the cow-calf sector—the breeding herd—the least concentrated component of the supply chain.⁵ Different from the cow-calf sector, however, the feedlot phase is highly concentrated in a few huge players: 5%

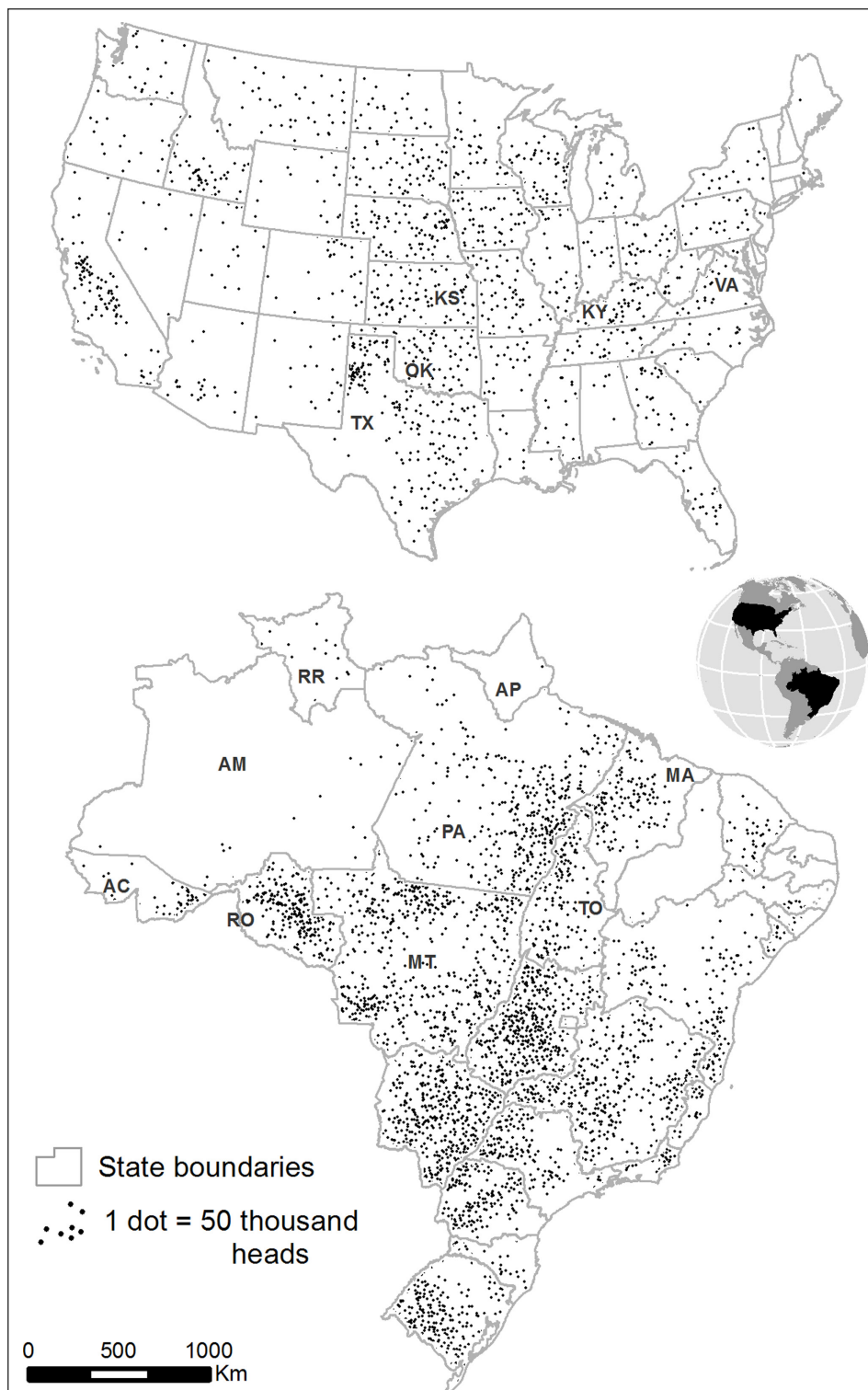


Figure 1: Geography of the cattle herd in the U.S. (USDA, 2014) and Brazil (IBGE, 2014). In U.S.: Texas (TX), Oklahoma (OK), Kansas (KS), Kentucky (KY), and Virginia (VA). In Brazil: Acre (AC), Rondônia (RO), Amazonas (AM), Roraima (RR), Amapá (AP), Pará (PA), Maranhão (MA), Mato Grosso (MT), and Tocantins (TO). While the US herd totals 89 million heads by 2013, Brazil's has surpassed 215 million. (See Table 1 for additional comparison). DOI: <https://doi.org/10.1525/elementa.224.f1>

of the feedlots account for more 90% of all fed cattle and 40% of production is done in feedlots of 35,000 head or more, and, at any given moment, approximately 10.5 million head are in feedlots.⁶ Even with this intensive model, however, there are still some 270 million ha dedicated to pasture in the U.S.⁷ and about 30 million ha dedicated to crops for livestock feed.

Rural landowners in the U.S., including cattle producers, have received consistent government support for production (Skaggs, 1986) and often keep small herds to secure agricultural tax benefits. Today there are more than a dozen subsidies directly aimed at livestock, including for example the Livestock Forage Disaster Program, which has paid out 4.5 billion dollars in drought related relief to ranchers over the past decade.⁸ Furthermore, crop subsidies (mainly corn) and crop insurance provide additional support for the fattening phase. In addition, U.S. taxpayers subsidize cattle ranching on the publicly-owned western plains to the tune of \$125 million or more every year (Glaser et al., 2015).

During the period between 1850s and 1920 the processing industry went from a regional and seasonal affair, with 185 plants in operation, to a network of more than 1,000 plants that was a key player in employment and the national economy (Skaggs, 1986). Technological innovations during this period, including the advance of the railroads (which grew in distance more than 8-fold), refrigerated trucks, automated killing floors, and packaging, facilitated this expansion. Early meatpacking was dominated by five or six firms, which eventually controlled more than two thirds of all processing, with stockyards located primarily in Chicago (Rifkin, 1992). The processing facilities then moved to the Western plains just before World War I and continued in force thereafter. The domination of the processing by a few firms had tremendous consequence in poor oversight,

political machinations, and beef quality and prices—the concentration in the market leads to lower prices for the producer and with market control higher prices for the consumer (Skaggs, 1986; Leonard, 2014). However, not much has changed: as late as 2009, four companies (Tyson, Cargill, National Beef and the Brazilian firm JBS)⁹ controlled 85% of beef processing, 65% of pork, and only three companies were producing one half of the chicken in the U.S. These companies also wield extraordinary political power to influence national food policies (Nestle, 2003). Furthermore, the market is moving towards direct contracts between producers and processors, which is eliminating competition and reducing bargaining power on the part of the producer (Leonard 2014).

Today the Beef industry in the U.S. is an expressly intensive model of production that maximizes rates of growth and is dependent on CAFOs. Also, the industry is dominated by a few processing companies. But it still requires extensive areas of pasture for calf production and relies heavily on government subsidies and financial underpinning. It is also widespread at the base, with many small breeding herds, and then highly concentrated in the feedlot and processing stages. Finally, even with increasingly thin production profit margins (Marsh 2003) and beef consumption declining—U.S. per capita consumption has dropped more than 40% since 1976 (**Figure 2**)—the herd population has declined by only 30% in 40 years.

The Brazilian beef industry

In similar fashion to the U.S., cattle arrived in Brazil alongside European settlers and gradually spread throughout the country. The first animals to arrive in the current state of Bahia were Zebu (*Bos indicus*) from the Cape Verde islands. At the onset of colonization cattle

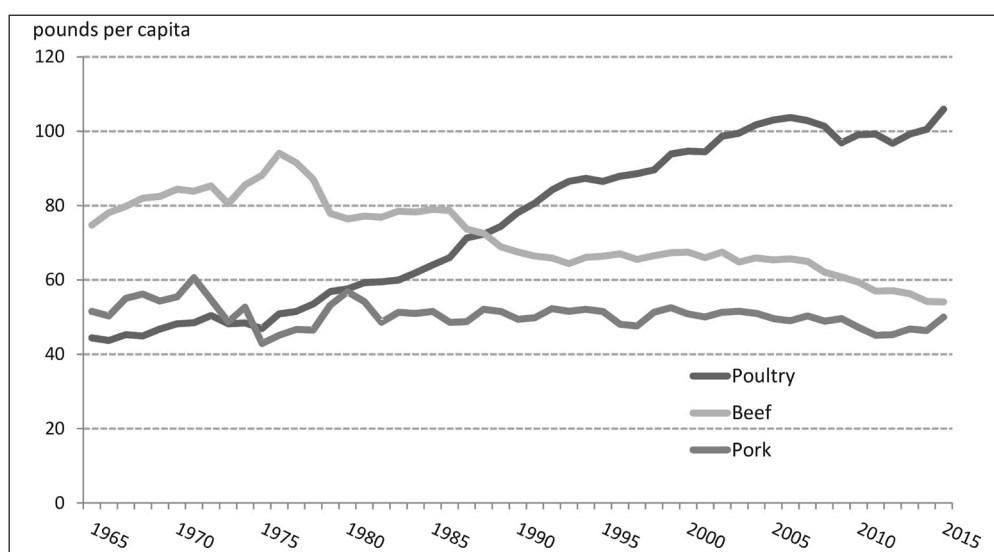


Figure 2: U.S. Per Capita Consumption of Beef, Pork and Poultry from 1965 to 2015. Source: USDA – data reprinted at <http://www.nationalchickencouncil.org/about-the-industry/statistics/per-capita-consumption-of-poultry-and-livestock-1965-to-estimated-2012-in-pounds/> (accessed May 31, 2015). DOI: <https://doi.org/10.1525/elementa.224.f2>

played an important role as draft animals for sugarcane mills (Brazil's first monoculture) along the fertile northeast coast. By the mid 17th century, however, as the animals increasingly competed for space with highly profitable sugarcane production, the Portuguese crown issued a decree banning cattle ranching within 80 km of the coast (Sousa, 2014). The herd was then used as a means to occupy the northeast hinterlands and, as a result, expanded to provide meat for major coastal towns. By the end of 17th century, ranching had become a key means to settle the country. Cattle properties, some larger than Portugal (Fausto, 1994), were characterized by extensive ranching and free labor (including Indigenous and half-blood cowboys) and occupied vast swaths of the outback (called *Caatinga*, a thorny dry ecosystem) in the northeast of the country. By this time, the Brazilian herd had grown to a population of more than a half million head.

At the beginning of 18th century, the need to supply meat to the rich gold mining regions of Minas Gerais led the herd expansion from the Northeast through the São Francisco river valley (known as the River of Corrals) to the central plateaus of the Brazilian Cerrado and the mountainous regions of the Atlantic Forest in Southeastern Brazil. At the same time, extensive ranches also started to expand in the Pampas in Southern Brazil. Good physiographic conditions, including natural grasslands, favored these southern lands and they become the principal source of animals, dry meat, and leather to the other parts of Brazil by the end of 18th century.

In the 1950s and 60s, the basis for the current herd was created by an influx of high quality Nelore, Guseat and Gir Bulls (all *Bos indicus* breeds) from India. These animals were largely limited to the southern states until the outset of 1970s when the Brazilian government decided to occupy the Amazon, resulting in the explosive growth of the herd following pastureland expansion in the Amazon and surrounding Cerrado regions. And, while the national herd increased by 60% between 1987 and 2013, the herd in Amazonian states of Mato Grosso, Pará, Acre, Rondônia, Roraima, Amazonas, Tocantins, Amapá, and Maranhão almost tripled (283%). During this process the Instituto Nacional de Colonização e Reforma Agrária (INCRA), founded in 1970, supported the settlement of families into the hinterland, in much the same fashion as the U.S. Homestead Act. In comparable numbers and a similar 50-year timeframe to the U.S., the Brazilian settlement program has now settled an estimated 800,000 families on farms of up to 100 ha each (Lima et al., 2006). As part of their household strategy, these families often have a small cattle herd of up to 30 head (Merry et al., 2008). This process has created a widespread and informal breeding herd.

Ranching continues to be a development priority for the Brazilian government. A newly minted program launched in 2014, revealingly called the "More Ranching Plan" (MAPA, 2014a), hopes to double beef production by growing the herd size to 300 million head (a 40% increase) and increasing productivity from 1.1 animal units (AU) per ha to 2.6. Intensification, therefore, is on the government development radar and given the potential profits,

cultural demand, and political co-benefits, will likely continue to receive significant investment and subsidy. Currently more than 30% of rural development lending in Brazil (U.S. \$18 billion per year, as of 2012) is allocated to ranching. Furthermore, the development goals underpinning settlement programs effectively subsidize land ownership, which increases the area available to ranch. All these social and economic development plans lead to more pasture and a greater supply of cattle, and perhaps unwittingly may offset any conservation impacts that intensification may create.

Furthermore, the link between beef productivity and the rate of deforestation is not clear. Between 1993 and 2004, while deforestation rates were at their highest, the process of intensification began and beef production per ha increased five-fold from 0.75 *Arroba*¹⁰ ha⁻¹ year⁻¹ to 3.8 *Arroba* ha⁻¹ year⁻¹ (Figure 3). In the following 8 years, between 2004 and 2012, deforestation plummeted by 80% while beef productivity dropped only 25% to 2.8 *Arroba* ha⁻¹ year⁻¹. Meanwhile, the industry-wide stocking rate, which does not account for the adoption of CAFOs, increased from 0.55 animal units (AU) per ha in 1987 to 0.8 AU per ha in 2003,¹¹ and has since held steady during a period when deforestation rates were changing rapidly. In contrast, the relationship between the percentage change in herd population (annual growth or decline) and deforestation rates appears to be more correlated, following broadly similar patterns of change (Figure 4). Finally, if we compare pasture area, which has had a steady annual increase between 1987 and 2013 of 3.8%, to herd population (annual increase of 5.3%) and beef production (increase of 7%), we see a pattern whereby there have been relative herd population increases and productivity improvements even as the area of pasture was on the rise (Figure 5).

Nevertheless, confined feeding is undeniably a part of the future of beef production in Brazil (Beefpoint, 2015; Rabobank).¹² Of the approximately 43 million head slaughtered in Brazil each year, 4.7 million head (11%) are now finished in CAFOs (Instituto FNP, 2013). Slightly less intensive are the so-called *lavoura-pecuária* (agro-pastoral) forms of intensification, whereby animals are brought in at 2 years old and finished in rotational pasture with grain. These systems are sprouting up mainly in conjunction with soy production, where corn often doubles as a second crop and grain is easily accessible (a 500-km radius of production), and is one of the reasons that Mato Grosso, a major soy and corn producer,¹³ has become the epicenter of intensification in Brazil increasing CAFO populations by 30% annually between 2010 and 2014 (Instituto FNP, 2015). It may be the case that intensification is focused on the steer population, which is being fattened in CAFOs, but there is still a large area in pasture. A lot of that pasture is and will be cow-calf operations, which have limits on per ha productivity, as well as in smallholder systems with herds of less than 30 head (Merry et al., 2008). This implies that costly investments in pasture restoration (Strassburg et al., 2014; Marcuzzo & Lima, 2015) may be ineffective as the industry moves to a greater dependency on grain-dependent semi-intensive and intensive

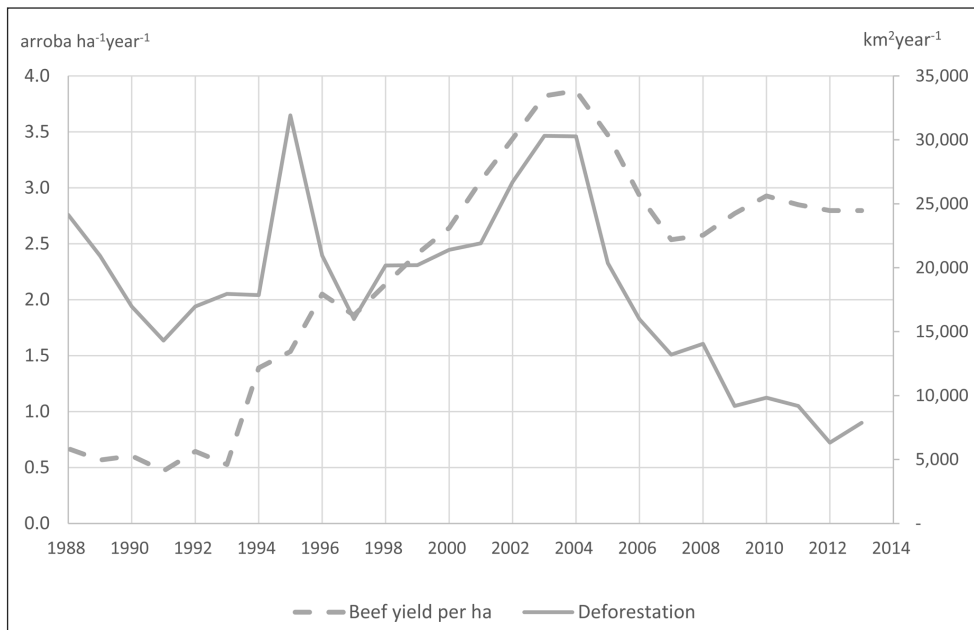


Figure 3: Comparing beef productivity ($\text{Arroba ha}^{-1} \text{ year}^{-1}$) and annual deforestation ($\text{km}^2 \text{ year}^{-1}$). Beef productivity ($\text{Arroba ha}^{-1} \text{ year}^{-1}$) is calculated by using annual variation in herd weight plus yearly meat production (Instituto FNP, 2014). States include: Acre (AC), Amapá (AP), Amazonas (AM), Maranhão (MA), Mato Grosso (MT), Rondônia (RO), Roraima (RR), Pará (PA), & Tocantins (TO). Time series of deforestation for the nine states that comprise the Brazilian Amazon and surrounding Cerrado come from INPE (2014) and LAPIG (2014). DOI: <https://doi.org/10.1525/elementa.224.f3>

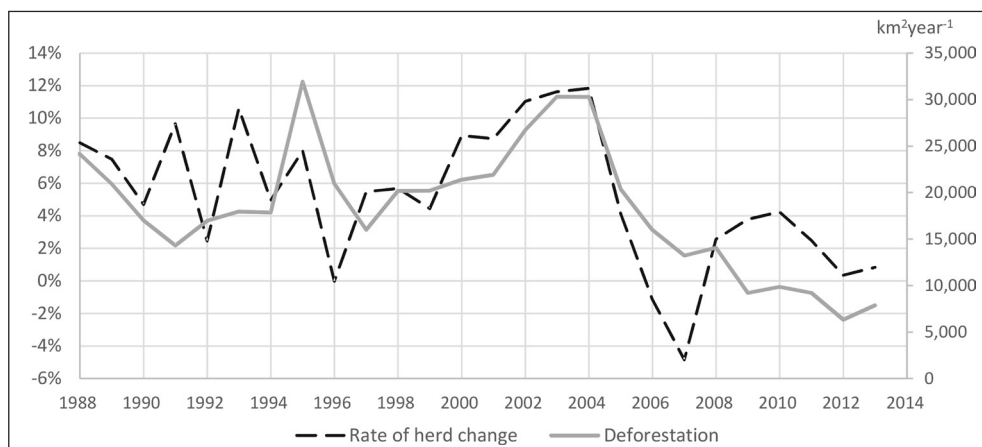


Figure 4: Deforestation rates and percent change in herd population. Time series of deforestation for the nine states that comprise the Brazilian Amazon and surrounding Cerrado come from INPE (2014) and LAPIG (2014) and rates of herd change—percent gain or loss of number of animals from IBGE (2014). DOI: <https://doi.org/10.1525/elementa.224.f4>

feedlotting for fattening, but continues to be dependent on extensive cow-calf operations for raw material.

So, the Brazilian beef industry has already begun to intensify. But contrary to the claim that higher productivity increases profits (Strassburg et al., 2014; Marcuzzo & Lima, 2015), it is unlikely that intensification will bring additional profits to the landowner. In the past few decades, profit margins in beef production in the U.S., a highly productive system, have consistently declined, driving many producers out of business (Marsh, 2003; Marsh and Brewster, 2004). The cattle industry in Brazil faces a similar trajectory: from the 1980s to 2000s, real

beef prices plummeted by 50% while costs increased by 50% over inflation rates (Exagro, 2014). Even though prices have recently recovered to early 2000s levels, profit margins have narrowed due to increased calf prices.¹⁴ The intensified model creates negative environmental and health externalities (e.g., antibiotic use and water use or pollution) and runs the risk of becoming a non-competitive, and unprofitable, market dominated by the processing sector.

The processing sector in Brazil is becoming more concentrated and is focusing market share into companies that receive significant financial subsidy through access

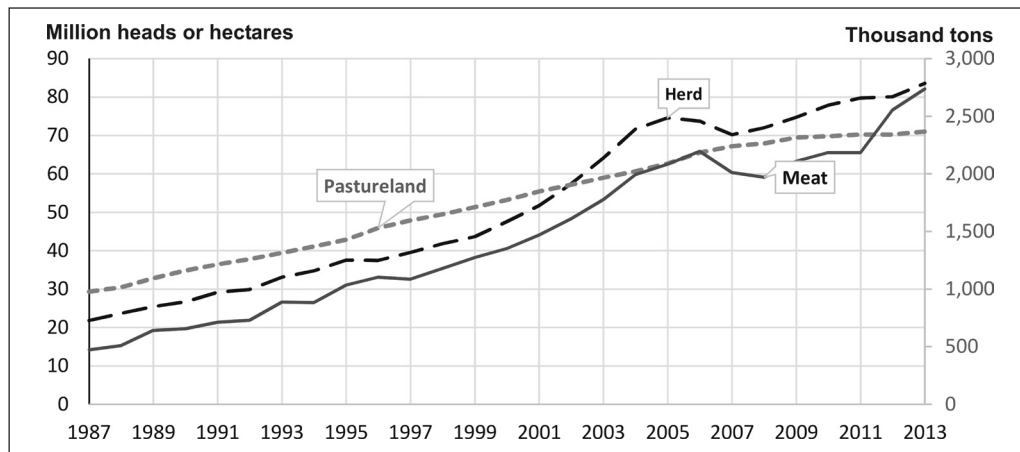


Figure 5: Herd growth, pastureland, and meat production in the Amazon and Cerrado from 1987 to 2013.

For calculation of pastureland, we integrated data by state on deforestation in the Cerrado (LAPIG, 2014) and in the Amazon (INPE, 2014), as well as cropland time series (CONAB, 2014). LAPIG's data was extrapolated to 1987 by using the average for years 2002–2004. Pastureland as of 2012 comes from Soares-Filho et al. (2014). Meat production comes from Instituto FNP (2013); heard size comes from (IBGE, 2013). Statistics include the states of Acre, Rondônia, Amazonas, Roraima, Amapá, Pará, Maranhão, Mato Grosso e Tocantins. DOI: <https://doi.org/10.1525/elementa.224.f5>

to government lending as well as favorable political access (Economist, 2010).¹⁵ Between them, JBS and Marfrig, the second largest meat processing company in Brazil, have received around 8 billion dollars in loans by 2010 (equivalent to about 3 billion dollars in subsidy due to preferential loan rates and terms) from Brazil's development bank (BNDES), which now owns more than 20% of JBS (Economist, 2010); with this support JBS increased its sales from approximately 2 billion dollars in 2005 to 45 billion in 2013. JBS now controls 31% of all meat processing in the country and 12 percent worldwide. As owner of Swift, Pilgrims Pride, Bertin, and other brands, and with operations in Australia, the U.S., Mexico, Brazil and Argentina, JBS is the largest meat processing company in the world. Marfrig and Minerva, the next biggest processors, control seven and five percent, respectively, of the Brazilian market (Macedo and Lima, 2012). Furthermore, JBS appears to expect great growth in the Brazilian herd in the foreseeable future with production costs being much lower than in the U.S. (Economist, 2010). This oligopsony¹⁶ (few buyers) mirrors the reality of the U.S. (Skaggs, 1986), with the predictable outcomes of lower prices to producers and, since there are also few sellers, higher prices for consumers. Indeed, JBS has been the focus of anti-trust scrutiny in both Brazil and the U.S.¹⁷

While large companies such as JBS have demonstrated localized success in cleaning its supply chain in parts of the State of Pará where they are a regional de-facto monopsony (Gibbs et al., 2016), they continue to buy from ranchers in other regions regardless of their environmental performance (authors' field observation). In fact, a key player in the apparent supply chain improvements has been the Public Ministry of Brazil (MPF), which brings legal action against both private and public entities (Arima et al., 2014). Even the so-called cattle agreements, which are claimed as a conservation

success (Gibbs et al., 2016), were preceded by the MPF threatening JBS with legal action over environmental issues.

By continuing to provide cheap rural credit coupled with expansionist development policies, the Brazilian government increases the herd, which may inadvertently decrease production margins at the farm gate. At the same time, it is concentrating processing capacity in the hands of a few large companies through access to preferential credit or subsidies. In other words, this process resembles the U.S. experience and may soon mirror U.S. production history, perhaps not exactly, but in sufficient detail to merit consideration in policy design and conservation planning.

Conclusion and recommendations

Our side-by-side comparison of the development history and current conditions of beef production the U.S. and Brazil, which shows some clear historical and current similarities, opens the possibility to the idea that cattle intensification will occur independently and organically in response to the new economic conditions present in Brazil. Furthermore, the adoption of intensification technology and practice may increase exponentially should the institutional failures that favor extensive production be removed.¹⁸ We also suggest that the intensification model followed by the U.S., and after which Brazil seems headed, generates environmental and animal welfare concerns beyond deforestation, which should be carefully examined. Additionally, this model may be a poor choice over the long-term for both ranchers and consumers who are subject to the impacts of highly concentrated processing, wholesale and retail supply components, as well as exogenous incentives that create oversupply at the cow-calf component due to socially-oriented development policies.

We note that, even in the absence of directed conservation efforts, the U.S. beef industry has intensified,

experienced reduced profit margins at the farm gate, fallen to its lowest herd populations since the 1950s, and lost market share to other sources of protein: chicken and pork. During this process, however, the U.S. herd population declined by only 30% over a period of 40 years. Yet it still requires large natural resource inputs (Nickerson et al., 2011), receives significant government subsidies (Noble, 2016), and generates considerable negative environmental externalities.¹⁹

We also provide evidence that many of the historical and current conditions driving the intensification and eventual contraction in the U.S. are mirrored in Brazil—implying that beef production in Brazil may follow a somewhat similar path. In which case, the Brazilian sector will intensify and shrink as a result of policies that remove land from production and see an increase in the price of beef relative to other protein sources, thus dampening demand through competition. However, with intensification focusing on feedlots and fattening steers, the impact may not be significant in reducing the overall herd population. We suggest that intensifying beef production may have few or no attributable conservation outcomes, but instead holds the potential to simply redirect negative externalities. Furthermore, a highly concentrated processing sector wields a disproportional level of political and market influence, and tends to seek profit maximizing rather than socially optimal solutions, possibly making them unreliable conservation partners.

The inescapable truth of beef production is that it is one of the least efficient transformations of energy into consumable calories (Eshel and Martin, 2006; Steinfeld et al., 2006), and whether driven by government policy, markets or custom, the increasing consumption of beef worldwide will undoubtedly have significant environmental impact (Rifkin, 1992; McAlpine et al., 2009). When compared to other livestock, 'efficient' beef production in the U.S. needs 28 times the land, consumes 11 times more water, produces 5 times more greenhouse gases and uses 6 times more nitrogen (Eshel et al., 2014). Approximately 36% of all calories produced worldwide are destined for animal feed (Cassidy et al., 2013) and in the U.S., 67% of crop production goes to producing feed for animal protein.²⁰ Finally, the emission of greenhouse gas from beef production in Brazil is increasingly attributable to enteric emissions (Bustamante et al., 2012). Thus, it is entirely possible that the only positive conservation outcomes to be gained in the long run within the industry would be through a significant reduction in beef consumption (Rifkin, 1992; McAlpine et al., 2009).

Our suggestion is that in order to limit the impact of frontier development, including ranching, on the forest estate, one should focus on causes, not symptoms, and look more closely at credit (Assunção et al., 2013), land tenure (Binswanger, 1991; Alston et al., 1999), illegal land use, infrastructure (Pfaff et al., 2007), as well as underlying development incentives, among other factors, and then strengthen existing protections afforded forests by protected areas, indigenous areas, and even multiple use forests (e.g. Soares-Filho et al., 2010; Nunes et al.,

2012; Azevedo-Ramos et al., 2015). There is also a growing argument for closing the frontier (Pacheco and Pocard-Chapuis, 2012), as the U.S. did in 1892, and halting the settlement programs, which would have the effect of making land scarce. These recommendations are not new, but relevant in the face of numerous publications suggesting there is direct conservation benefit to be gained by increasing beef productivity and managing the beef supply chain.

Notes

- ¹ www.ansi.okstate.edu/breeds/cattle/herford/.
- ² Angus now dominates more than 60% of the commercial beef herd. www.angus.org/Pub/AngHist.aspx.
- ³ The area of the U.S, not including Alaska, is 7.4 million sq km. Brazil is approximately 8.5 million sq km.
- ⁴ http://www.agcensus.usda.gov/Newsroom/2014/05_02_2014.php.
- ⁵ These statistics are found on the National Cattlemen's Beef Association website on June 2, 2014 (www.beefusa.org/beefindustrystatistics.aspx), but are widely available, with the United States Department of Agriculture (USDA) being a major data producer on all US agricultural production.
- ⁶ www.beefusa.org/uDocs/Feedlot%20finishing%20fact%20sheet%20FINAL_4%2026%2006.pdf.
- ⁷ <http://news.cornell.edu/stories/1997/08/us-could-feed-800-million-people-grain-livestock-eat>.
- ⁸ <https://farm.ewg.org/progdetail.php?fips=00000&progcode=livestock>. Ranchers in the States Texas and Oklahoma received approximately 30% of the subsidies, divided equally.
- ⁹ www.hcn.org/issues/43.5/cattlemen-struggle-against-giant-meatpackers-and-economic-squeezes/the-big-four-meatpackers-1.
- ¹⁰ The term "Arroba" is a common measure of live animal weight in ranching throughout Latin America and in Brazil is equal to 30 kg.
- ¹¹ For calculation of AU, we integrated data by state on deforestation in the Cerrado (LAPIG, 2014) and in the Amazon (INPE, 2016), herd size (IBGE, 2014), and herd distribution by age and weight (Instituto FNP, 2014) as well as cropland time series (CONAB, 2014). LAPIG's data was extrapolated to 1987 by using the average for years 2002–2004. Pastureland as of 2012 comes from Soares-Filho et al. (2014).
- ¹² <https://www.rabobank.com/en/press/search/2014/20141017-Rabobank-Rapid-intensification-of-Brazilian-beef-production-to-continue.html>.
- ¹³ Corn production has tripled in Mato Grosso between 2010 and 2013.
- ¹⁴ Calf prices in Mato Grosso during 2013 increased at more than twice the rate of beef prices (Instituto FNP, 2015). This localized supply shortage, and thus increased prices, is due to the rapid increase of CAFO capacity.
- ¹⁵ JBS was also the largest donor to the Rousseff's PT party and donated more than 114 million R\$ to various affiliated parties during the most recent campaign – <http://www1.folha.uol.com.br/poder/2014/09/1519452->

maior-doador-de-campanhas-concentra-repasses-a-governistas.shtml.

¹⁶ Regionally oligopsony turns to monopsony because in most Brazilian regions a single meatpacker often dominates the market.

¹⁷ <http://www.justice.gov/atr/cases/jbsnat.htm>.

¹⁸ See additional scenarios for the future of ranching in Barbosa et al. (2015).

¹⁹ <http://www.teebweb.org/agriculture-and-food/interim-report/>.

²⁰ <http://www.vox.com/2014/8/21/6053187/cropland-map-food-fuel-animal-feed>.

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Competing interests

The authors have no competing interests to declare.

Author contributions

Both authors contributed equally to the conceptual design, research and drafting of the manuscript.

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