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Short Communication

Land-saving approaches and beef production growth in Brazil

Geraldo B. Martha Jr.[a,b,*], Eliseu Alves[c], Elisio Contini[a]

[a] Embrapa Studies and Training, Brasília, DF 70770-901, Brazil
[b] National Council for Scientific and Technological Development (CNPq) fellow, Brasilia, Brazil
[c] Embrapa, President's Office, Brasília, DF 70770-901, Brazil

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ABSTRACT

Increased food production can be achieved by incorporating more land into the productive process, by increasing productivity in already opened areas or by a combination of both strategies. By allowing a fraction of current pasture area to accommodate the expansion of food and biofuel crops intensification of existing pastoral systems is a strategy to avoid further loss of native vegetation. However, there is a common misperception that the path of growth of the Brazilian beef production has been primarily based on the expansion of extensive pastures. Empirical evidence presented in this article shows that whilst this was the case for the 1950–1975 period, the pattern of cattle production in Brazil has changed profoundly since then. During the 1950–2006 period productivity gains explained 79% of the growth in beef production in Brazil and supported a land-saving effect of 525 million hectares. Therefore, without this land-saving effect an additional pasture area that is 25% higher than the Amazon biome in Brazil would be needed to meet current levels of Brazilian beef production.

1. Introduction

The main drivers that boost food demand are population growth and higher per-capita income. Changes in consumption habits associated with urbanization further increase food demand. The growth in demand resulting from agricultural commodities with high-income elasticity, such as animal protein products, is especially sensitive to higher per capita income and to urbanization in developing countries. Assuming constant food prices, the demand for agricultural products with income elasticity (of demand) from 0.5 to 0.75 – a range compatible with animal protein products in developing countries (Braun, 2005) – is expected to increase, on a yearly basis, from 2.4% to 3.6% in China, from 3.4% to 4.8% in India, from 2.1% to 2.8% in Russia, and from 2.1% to 3.0% in Brazil (Annex, Table A1).

If demand for food grows its supply has to grow at least at the same pace. Otherwise, food prices will increase and poor people, who spend a larger share of their earnings on food, especially in poor nations, will suffer the greatest impacts. In this scenario, increasing food supply at levels compatible with the growing demand is a high priority.

Increased agricultural production can be achieved by incorporating more land into the productive process, by increasing productivity in already opened areas or by a combination of both strategies. In Brazil, the majority of agricultural land in use is covered with pastures (~159 million hectares, or 73% of the total area with crops and pastures) (IBGE, 2011a). By allowing a fraction of current pasture area to accommodate the expansion of food and biofuel crops, intensification of existing pastoral systems is a strategy to avoid further loss of native vegetation. In this article we ask if the common perception that the path of growth of the Brazilian beef production has been primarily based on the expansion of extensive pastures (Soares-Filho et al., 2006; Fearnside, 2005; Nepstad et al., 2006, 2009) is supported by empirical evidence.

2. Methods

We used official statistics of the Brazilian Government, from the Brazilian Institute of Geography and Statistics (IBGE, 2011a, 2011b, 2011c) (Table 1) to arithmetically decompose the factors of beef production growth for the last five decades.

Beef production in pastures can be defined as: $p = y * a$, where "p" is production, "y" is productivity, and "a" is pasture area. Then consider that productivity can be expressed as $y = g * s$, where "g" is production ("p") per animal ("h") ($g = p \div h$), and "s" is the stocking rate ($s = h \div a$), that is, the number of animals per unit of pasture area in a given period, generally 1 year.

Taken together, we have the identity (1), a simple model that connects beef production to animal performance ("g"), stocking rate ("s") and pasture area ("a") without the need of using a production function theory:

* Corresponding author at: Embrapa Studies and Training, Brasília, Parque Estação Biológica (Pq. EB), Av. W3 Norte (final), DF 70770-901, Brazil.
E-mail address: geraldo.martha@embrapa.br (G.B. Martha Jr.).

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Table 1
Brazilian beef production characteristics, 1950–2006.

	Unit	1950	1960	1970	1975	1980	1985	1996	2006
Bovine population[a]	Head	46,891,208	56,041,307	78,562,250	101,673,753	118,085,872	128,041,757	153,058,275	171,613,337
Pasture area[a]	Ha	107,633,043	122,335,386	154,138,529	165,652,250	174,499,641	179,188,431	177,700,472	158,753,866
Production[b]	1.000 ton c.e.[d]	1083.67	1359.22	1845.18	1790.25	2083.77	2222.65	4053.18	6886.58
Stocking rate[c]	head/ha	0.44	0.46	0.51	0.61	0.68	0.71	0.86	1.08
Animal performance[c]	kg c.e./head	23.11	24.25	23.49	17.61	17.65	17.36	26.48	40.13
Productivity[c]	kg c.e./ha	10.07	11.11	11.97	10.81	11.94	12.40	22.81	43.38

[a] IBGE (2011a).
[b] IBGE (2011b, 2011c).
[c] Authors' calculations.
[d] c.e. is carcass equivalent.

$$p = g * s * a = \frac{p}{h} * \frac{h}{a} * a \quad (1)$$

Considering identity (1), the decomposition of the corresponding growth rates (designed by "r") of "p" (r_p), "a" (r_a), "g" (r_g) and "s" (r_s), between two successive periods, can be described as follows:

In the time $t = 0$, production is:

$$p_0 = \frac{p_0}{h_0} * \frac{h_0}{a_0} * a_0 \quad (2)$$

In the time $t = t$, subsequently to time $t = 0$, and considering the respectively growth rates of "p" (r_p), "a" (r_a), "g" (r_g) and "s" (r_s), production is:

$$p_0 * (1 + r_p) = \frac{p_0}{h_0} * (1 + r_g) * \frac{h_0}{a_0} * (1 + r_s) * a_0 * (1 + r_a) \quad (3)$$

Simplifying Eq. (3) lead to:

$$(1 + r_p) = (1 + r_g) * (1 + r_s) * (1 + r_a) \quad (4)$$

And, solving Eq. (4) gives:

$$(1 + r_p) = 1 + r_g + r_s + (r_g * r_s) + r_a + (r_g * r_a) + (r_s * r_a) + (r_g * r_s * r_a) \quad (5)$$

Rearranging Eq. (5) we have:

$$r_p = r_g + r_s + r_a + (r_g * r_s) + (r_g * r_a) + (r_s * r_a) + (r_g * r_s * r_a) \quad (6)$$

If the interaction components are sufficiently small, which is frequently the case, Eq. (6) means that the rate of growth in beef production (r_p) can be approximately estimated by the sum of its additive components, e.g., the rate of growth in animal performance (r_g), stocking rate (r_s) and pasture area (r_a).

The growth of animal performance (r_g) is brought about grazing animal genetics, health, nutrition and forage nutritive value/management. The growth of stocking rates (r_s) reflects mainly soil fertility and also the ability of forage plants to use soil nutrients more efficiently. And the growth in pasture area (r_a) is related to an intricate myriad of factors such as real state opportunities, beef prices, available mechanization technology and the terms of trade for modern inputs.

In a second step, we estimated the land-saving effect arising from productivity gains in the Brazilian beef sector for the same period using Eq. (7):

$$\text{Land saving effect} = \frac{p_f}{y_i} - a_f \quad (7)$$

where p_f is the production in the final year (1000 tons of carcass equivalent); y_i is the productivity in the initial year (kg of carcass equivalent/ha) and a_f is the pasture area in the final year (million hectares).

We then confronted these land-saving results *vis-à-vis* the ones calculated with USDA's and FAO's beef production dataset (USDA, 2011; FAO, 2011). For the 1996–2006 period we could further disaggregate the factors of growth and land-saving analyses by regions (North, Center-West, Southeast, Northeast, and South). For instance, the Brazilian Northern Region encompasses the whole Amazon Biome and the majority of the Legal Amazon, a political geographic division that includes in addition to the Amazon Biome the Savannah-like ("Cerrado" in Portuguese) Biome in Tocantins, Maranhão and Mato Grosso States.

3. Results and discussion

Brazil's beef production increased 6.35 times between 1950 and 2006 (Table 1), from 1084 to 6887 thousand metric tons of carcass-weight (mtcw) (IBGE, 2011b, 2011c), representing an impressive annual growth rate of 3.36%. Brazil thus became a major player in the international beef market in the last decades. Comparing the period 1970–1997, Brazilian beef exports experienced a modest change: from 124 thousand mtcw to 158 thousand mtcw (USDA, 2010; MAPA, 2011). However, in the following decade, Brazil became a major beef exporter, with a peak volume of 1523 thousand mtcw in 2006, that decreased to 1231 thousand mtcw by 2010 (USDA, 2010; MAPA, 2011). Brazil's share in global beef exports in the 1996–2010 period jumped from 5.3% to 23.1%, peaking at 28.9%, in 2007 (USDA, 2010). Brazil's share in the world beef market in 2019 may represent 29–30%, accounting for approximately 2500 thousand mtcw of beef exports (MAPA, 2011; OECD, 2010).

3.1. Factors of growth in Brazilian beef production

After the factors of beef production growth for the 1950–1975 period were decomposed, it was found that productivity explained a small part of it (around 14%). Pasture area increase, strongly associated with the expansion of the agricultural frontier, was the major factor explaining about 86% of the beef production growth in Brazil up to 1975 (Fig. 1).

Pasture area reflects an intricate myriad of factors such as real state opportunities, beef prices, available mechanization technology and the terms of trade for modern inputs. It is reasonable to argue, however, that pasture area expands or shrinks to a large extent in response to the opportunity cost of pastoral systems compared to other land-use alternatives, for a given level of risk, and to Governmental (dis)incentives.

In the case of Brazil, the increase in pasture area seemed to have responded to both the low opportunity cost of "extensive" cattle ranching, compatible with the early period of the agricultural frontier, and also to Governmental investments in development programs and in the establishment of the necessary infrastructure in the Cerrado and in parts of the Amazon. Furthermore, the need to secure land tenure of cattle ranches (clearing, building fences, patrolling the borders, paying taxes, etc.) due to lack of formal

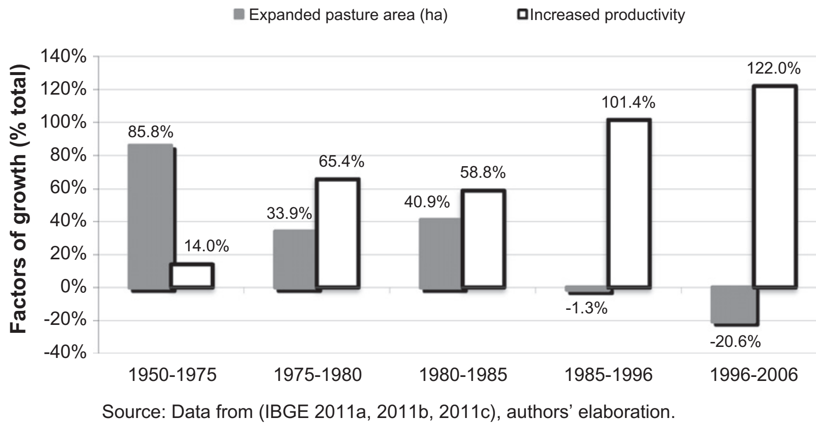

Fig. 1. Factors explaining beef production growth in Brazil, 1950–2006.

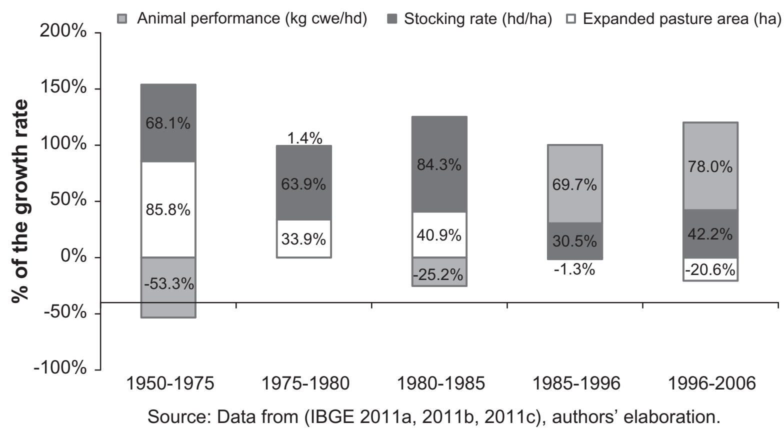

Fig. 2. Factors explaining beef production growth in Brazil, with productivity effects disaggregated, 1950–2006.

properties rights (Mueller, 1997) seemed to have played a decisive role in explaining these trends.

Whereas the farmers' strategy of increasing pasture area was still important in the 1975–1985 period, it had lost its impetus. In that decade, productivity gains already explained around 65% of beef production growth in Brazil. Nevertheless, farmers' initial low schooling and limited financial resources, and the lack of legal land ownership hampered an even higher rate of technology adoption. In the subsequent period, after 1985, but in particular after 1996, pasture area negatively contributed to beef production (Fig. 1), because total pasture area in Brazil has decreased since then (Table 1).

Until 1985, production per animal negatively contributed to beef production growth (Fig. 2). Apparently, during this period of rapid pasture area expansion investments in animal performance, in general, seemed to be disregarded. The production per animal reflects mainly improved animal genetics, health and nutrition (mineralization and feed supplementation). Improved forage quality, through better pasture nutritive value and management also contributes to enhance the overall animal performance. All these factors – genetics, health, nutrition and forage nutritive value/management – experienced consistent growth and widespread adoption especially after the late 1980s. It thus explains the positive and relevant role that production per animal played after 1985, accounting for 65–70% of (the positive) beef production growth in the past two decades (Fig. 2).

Stocking rates depend on pasture production, reflecting soil fertility and also the ability of forage plants to use soil nutrients more efficiently. Stocking rates responded for 44–67% of (the positive) beef production growth up to 1985 (Fig. 2). In that period, both native soil fertility and the widespread adoption of better-adapted *Brachiaria* grasses were decisive in beef production growth. In the subsequent decade (1985–1996) stocking rates' contribution to beef production expansion declined to around 30% but increased again to explain 35% of beef production growth in the 1996–2006 period. Inadequate soil fertility maintenance practiced in Brazilian pastoral systems (Martha et al., 2007) and the faster improvements in production per animal explain the relative decrease in contribution of stocking rates in accounting for beef production growth in recent decades. Investing in animal performance is obviously important. However, if investments in pastures (stocking rates) lag too far behind, the sustainability of pastoral systems will inevitably be jeopardized.

At the regional level, pasture area contributed negatively to beef production growth in the 1996–2006 period in all regions but the

Table 2
Factors of beef production growth and land-saving effect from productivity gains in the sector, Brazil, 1996–2006. Data from IBGE (2011a, 2011b), authors' elaboration.

Region	Factors of beef production growth (% total)			Land-saving effect (million hectares)
	Expanded pasture area	Increased stocking rate	Improved animal performance	
Brasil	−20.59	42.21	77.96	143.17
North	5.58	34.68	56.01	73.24
Northeast	−8.06	25.27	82.06	27.31
Southeast	−72.79	62.06	113.27	29.79
South	−186.79	112.92	179.06	8.38
Center-West	−14.65	41.34	72.68	41.45

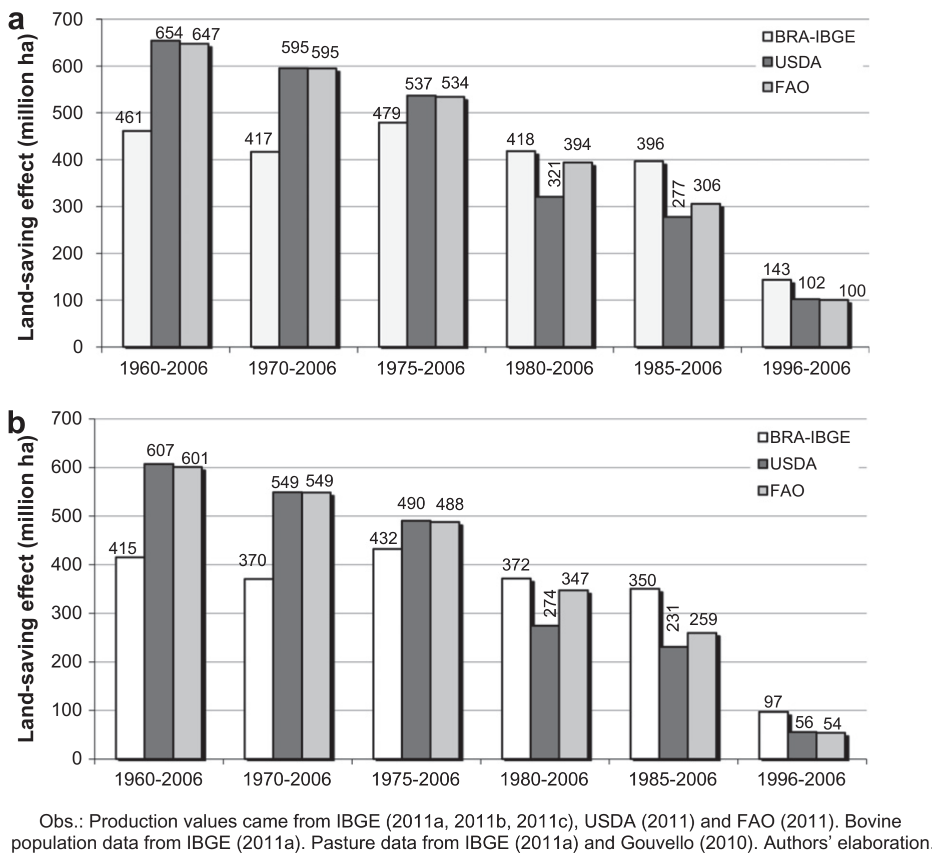

Fig. 3. Land-saving effects from productivity gains in Brazilian beef production considering pasture area values of 159 M ha (a) and 205 M ha (b), 1960–2006.

North. Even in that case (e.g. North region), pasture area expansion explained less than 6% of beef production growth. Increased stocking rates explained roughly 35% of beef production growth in Brazil while the remaining 65% came from improved animal performance (Table 2). Maintaining this pace of productivity increase will demand: (1) pasture production maintenance in the long run, through direct pasture fertilization and/or carry-over fertilizer effects arising from fertilizers applied on crops (such as in integrated crop-livestock systems); and, (2) continued investments in technologies to improve animal performance. Without these land-saving actions, further increases in Brazilian beef production would rely on pasture area expansion.

Deforestation for new pasture establishment is not a desirable option for future developments in agriculture. Therefore, the competitiveness of the Brazilian beef sector, already supported by productivity, will increasingly depend on additional productivity gains. Incentives (such as payments for environmental services) to accommodate modern inputs use in the system, especially when terms of trade are unfavorable, is possibly a valuable complementing action.

3.2. Land-saving effects from Brazilian beef production

The land-saving effect due to productive gains in Brazilian beef sector reached a total of 525 million hectares in the 1950–2006 period. Without this land-saving effect an additional pasture area of about 525 million hectares, that is 25% higher than the Amazon biome in Brazil, would be needed to meet 2006 levels of beef production in Brazil. Using FAO (FAO, 2011) and USDA (USDA, 2011) beef production datasets, and considering pasture areas ranging from 159 to 205 million hectares (IBGE, 2011a; Gouvello, 2010), for the 1960–2006 period, the land-saving effect varied from 601 to 654 million hectares (Fig. 3).

In the 1996–2006 period, an estimated area of 73 million hectares was spared in the "Amazon" (North region) as a result of productivity gains in beef production. At the regional level, land-saving effects deriving from productivity gains in the beef sector represented 8 (Southern region) to 73 million hectares in the 1996–2006 period (Table 2).

4. Conclusions

Beef production in Brazil has often been criticized as a low-productivity industry that is economically feasible only through the expansion of pasture area. Whilst this was the case for the 1950–1975 period, the pattern of cattle production in Brazil has since then profoundly changed toward a consistent pattern of growth supported by productivity gains. Indeed, between 1950 and 1975, productivity grew by only 0.28% per year, increasing to 3.62% per year from 1975 to 1996, and accelerating to an impressive 6.64% per year in the 1996–2006 period. Thus, the greatest share of technological change in the Brazilian beef industry took place in the recent past.

Overall productivity gains have reflected a huge agricultural research effort that has generated important spillovers of knowledge and technology to farmers. Further advances on this sustainability path, while challenging, will ensure the continuity of beef growth with land-saving effects. The observed increase in animal performance from 17.61 kg c.e./head to 40.13 kg c.e./head in the 1975–2006 period further contributed to lower methane emission intensity (i.e. methane emissions per product unit). Thus,

Table A1
Projected effects of increases in population and in per capita gross domestic product (GDP) for different income elasticities of demand assumptions in food demand growth rate.

	Growth rate (%/yr. 2009–2050)		Income elasticity			
	Per capita GDP[a]	Population[b]	0.10	0.25	0.50	0.75
			% growth rate in food demand[c,d]			
United States	1.79	0.61	0.79	1.06	1.51	1.95
China	4.61	0.13	0.59	1.28	2.43	3.59
India	5.37	0.73	1.27	2.07	3.42	4.76
Russia	3.04	0.55	0.86	1.31	2.07	2.83
Brazil	3.61	0.29	0.66	1.20	2.10	3.00
Mexico	3.23	0.40	0.72	1.21	2.01	2.82
Turkey	3.38	0.65	0.98	1.49	2.34	3.18
Indonesia	4.06	0.55	0.96	1.57	2.58	3.60

[a] PWC Projections (2011).
[b] UNPD medium variant projection of the world population to 2050 (UNPD, 2010).
[c] Constant food prices are assumed.
[d] Authors' calculations.

increasing public and private R&D funding and developing sound-policies to boost farm productivity will have effects on long-term farm production while avoiding further deforestation (due to the land-saving effects arising from productivity gains) and reducing greenhouse gas emissions.

It must be recognized that farmers are the agents that transform research results into technologies. To achieve new levels of technology adoption, they need knowledge and skills; therefore, training and investment in well-developed extension strategies is of utmost importance to further advance on a productivity path. As human capital requires time to be improved, policies targeting widespread education strengthening are also needed.

New technologies will be adopted when they prove to be competitive against existing alternatives already in use and when relative prices are favorable (Martha et al., 2011). Such new technologies demand capital, which in some cases may prove to be an outstanding problem. This, however, can be solved by a competent credit policy, while access to more complex machinery and equipment can also be solved by amending the renting and leasing legislation (Alves, 2008). Incentives, in terms of innovative and adequate financing mechanisms, might eventually be used to accelerate the large-scale adoption of land-saving technologies in Brazilian beef production.

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Appendix A

See Table A1.

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