

The Viability of Cattle Ranching Intensification in Brazil as a Strategy to Spare Land and Mitigate Greenhouse Gas Emissions

Working Paper No. 11

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Abstract

Recent research and policy on reducing greenhouse gas (GHG) emissions in Brazil suggests that the least-cost, largest-scale mitigation option is for cattle ranchers to produce more on the land they already use. The rationale is that cattle ranching intensification programs (CRIPs) can speed yield-increasing technology adoption that delivers GHG benefits by sparing land to prevent deforestation and allow more biofuels production and other productive uses. We draw on a literature review to assess the merits and viability of CRIPs in Brazil. Support for CRIPs is based on a series of premises: accelerating intensification is straightforward and additional; Brazilian pasturelands have significant potential for alternative uses; reducing extensive cattle ranching will have a substantial effect on deforestation rates; increasing intensive ranching will reduce extensive cattle ranching; boosting intensity will actually spare land because it won't simply cause demand to increase; increased intensity has social and environmental co-benefits; and the mitigation benefits of CRIPs outweigh the marginal costs. We examine the logic and the inconsistencies of each premise, weigh potential consequences and propose potential remedies that could improve the viability of CRIPs.

Keywords

Climate change mitigation; REDD; agricultural productivity; avoided deforestation; cattle ranching intensification; land use intensification; Brazil; marginal lands; agricultural statistics; cattle ranching and deforestation.

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Acronyms

CRIPs	Cattle Ranching Intensification Programs
GHGs	Greenhouse Gas Emissions
NAMAs	Nationally Appropriate Mitigation Actions
UN-REDD	United Nations Reduced Emissions from Deforestation and Forest Degradation
LUC	Land Use Change

Introduction

The potential for interventions to reduce the pressure of agriculture on forests has become central to debates over the future of biofuels and has become an explicit focus of negotiations on Reducing Emissions for Deforestation and Forest Degradation (UN-REDD). One proposal is land sparing, the concept of boosting output of agricultural land already in use to make room for forests and other productive uses. This paper examines the viability of one intervention that intends land sparing—cattle ranching intensification programs (hereafter CRIPs) in Brazil. We define CRIPs as interventions for reducing GHGs by increasing the intensity of cattle product output per unit pastureland.

Momentum for Brazilian CRIPs may have originated with livestock researchers (Serrao & Toledo 1990; Arima & Uhl 1997) but it now comes from a variety of sources including NGOs, governments and the scientific community (UK Renewable Fuels Agency 2008; Sajwaj et al. 2008; Nepstad et al. 2009; Ecofys & Winrock International 2009; Manzatto et al. 2009; Embassy of Brazil 2010; Gouvello 2010; Angelsen 2010; Boucher et al. 2011; Amend et al. 2011; Searchinger & Amaral 2009; Ecofys 2011). It is reflected in Brazil's Nationally Appropriate Mitigation Actions (NAMAs), which, up until now are the best hint of how climate mitigation policies in Brazil might develop (Embassy of Brazil 2010).

Brazil's NAMAs identify roughly one billion tons of climate mitigation potential by 2020. The NAMAs commit just 10% of total mitigation to come directly from changes in cattle ranching practices. However, based on an analysis we conducted of the World Bank report on which the NAMAs appear to be patterned, we estimate that roughly 90% of the mitigation suggested would come from increased cattle ranching productivity to reduce deforestation and spare land for crop agriculture¹. As Gouvello (2010:28) describes it, "Increasing

¹ The NAMAs letter does not explicitly state which mitigation actions CRIPs facilitate, but the NAMAs targets are nearly identical to targets published in Gouvello (2010) a report compiled by leading Brazilian climate scientists and published by the World Bank. The report clearly states the central role of land sparing for facilitating most GHG mitigation it proposes. The following passage is the best summary: "To avoid emissions from deforestation, ways would need to be found to reduce global demand for land, while maintaining the same level of products supply as in the reference scenario. In systemic terms, the mitigation of emissions through land-use change could be achieved by absorbing the expansion of these activities via the increased productivity of other ones. Brazil's major agricultural activities already show high levels of productivity and consequently do not offer opportunities to increase productivity on the scale required to absorb these additional levels of demand for land. For example, the productivity of a soybean plantation in Brazil was 2.86 tons per ha in 2008, compared with 2.81 tons per ha in the United States (table 3.2). Beef-cattle farming shows much greater potential for increasing productivity

...intensification of livestock-raising can play an essential role in reducing the need for land..., while releasing the land required for expansion of other activities.”

The ranching focus of Brazil’s NAMAs is a choice that may well emerge from a series of assumptions about cattle ranching systems that are necessitated by gaps in data and scientific knowledge germane to cattle systems and GHG mitigation. One example of how this affects assessments of climate mitigation potential from ranching is the modeling approach taken by a team of leading Brazilian scientists who worked to produce a World Bank report outlining pathways for climate change mitigation in Brazil (Gouvello 2010). The Gouvello team imposes a constraint on the total area of land available for use as pasture in Brazil and a constraint across scenarios that holds constant total Brazilian livestock and agricultural output. By imposing the land constraint, the research team “frees” land in the simulation for forests and crops. Together, the two constraints cause the simulation of substantial GHG emissions reduction between the reference scenario and the low carbon scenario. The simulation demonstrates the greenhouse gas mitigation capacity of cattle ranching intensification in Brazil under these constraints, but raises questions about the sorts of programs that could actually elicit analogous effects in practice. The Gouvello team’s findings for cattle ranching mitigation potential are consistent with other investigations of climate mitigation in Brazil (Sajwaj et al. 2008; McKinsey & Co. 2009; Ecofys & Winrock 2009).

In the rest of the paper we use a literature review to examine the potential for Brazilian CRIPs as a viable strategy to reduce greenhouse gas emissions. We first explain the context for climate policy in Brazil, define key terms used in our analysis and then present premises, both explicit and implicit that underlie the rationale of CRIPs for some. We close with recommendation to advance the state of CRIPs.

per hectare, which can be applied to a much larger pasture area, since pastures occupy 207 million ha compared to 70 million ha for agricultural activities in 2030 in the reference scenario. Consequently, increasing the technological level and the intensification of livestock-raising can play an essential role in reducing the need for land for this activity, while releasing the land required for expansion of other activities.”

Table 1 Brazil's Proposed NAMAs

	Mitigation potential (mt CO ₂)	% of total mitigation
Restoration of grazing land	83-104	9%-11%
Integrated crop livestock systems	18-22	2%
Total ranching targeted	101-126	10%-12%
Reduction in Amazon deforestation	564	54%-58%
Reduction in <i>cerrado</i> deforestation	104	10%-11%
No-till farming	16-20	2%
Biological N ₂ O fixation	16-20	2%
Biofuels use	48-60	5%-6%
Total ranching related	748-768	77%-74%
All Ranching Contingent	849-894	85%-88%
Energy Efficiency	12-15	1%
Hydroelectric power production	79-99	8%-10%
Other alternative energy	26-33	3%
Total non-ranching related	117-147	13%-15%
Grand total	966-1041	100%

Source: Embassy of Brazil 2010; Gouvello, 2010

Context for Brazilian Climate Policy

The adoption of NAMAs is consistent with the fairly strong stance Brazil has adopted for GHG emissions controls in Northern countries and climate finance for mitigation in Southern countries.² Brazil had no formal climate policy of its own prior to 2008. In late 2008, then Brazilian President Lula da Silva signed a pledge committing Brazil to emissions reductions (President of the Republic of Brazil 2008). In December 2009 at the 15th Conference of the Parties in Copenhagen, Brazil pledged to achieve a 36-39% reduction in emissions relative to business as usual by the year 2020. The motivation to mitigate may stem from the vulnerability of Brazil's agriculture to climate change and deforestation³, the need to maintain access to agricultural markets where deforestation is a concern, and the potential for mitigation finance in forms such as the Amazon Fund, CDM-successor offsets, UN REDD and bi-lateral deals. Indeed, Brazil has somewhat coyly refused to classify its NAMAs as part of the Copenhagen Framework and this may be in part to maintain the option to accept finance in exchange for mitigation activities.⁴

Once resolved to mitigate, Brazil, like many Southern countries, has had little option but to address emissions from land use land use change and forestry (LULUCF) including

² Brazil has long favored emissions controls for Northern countries, but during the late 1990s, Brazil, more than other country, critiqued suggestions for developing countries to mitigate their greenhouse gas emissions. This critique took its strongest form in Brazil's 1997 proposal for mitigation commitments based not on annual emissions, but on cumulative, national responsibility for climate change. Such a proposal would have required developed countries to take responsibility for historic emissions in addition to current and future emissions. While this proposal failed, it fueled discussion of another Brazilian proposal, the Clean Development Fund, which was implemented by the UNFCCC as the Clean Development Mechanism (CDM). The CDM prohibited payments for avoided deforestation, a potential boon for Brazil's single largest stock of tropical forest. In 2005, a team of Brazilian and international scientists proposed a system for compensating reductions in deforestation. The proposal called for an offset system similar to the CDM, but it would explicitly pay for tropical forest conservation (Santilli et al. 2005). This proposal is an important antecedent for Reduced Emissions from Deforestation and forest Degradation (REDD).

³ Both Amazonian deforestation and global climate change threaten Brazilian agriculture and thus its economy and foreign exchange. Fully 80% of Brazilian cropland and cultivated rangeland is rain-fed and thus of heightened drought vulnerability (La Rovere & Pereira, 2007). Agriculture and agribusiness represent 25% of Brazilian GDP and 36% of Brazilian foreign exchange (La Rovere & Pereira 2007). Amazonian deforestation threatens ecosystem and agricultural productivity in all of Brazil's primary agricultural regions because forest regulates climatic conditions and rainfall cycles across much of the South American continent (Nepstad et al. 2008). Climate change, meanwhile, poses a threat to tropical agricultural productivity in general and Brazil is no exception. A combination of global climate change and Amazonian deforestation could be of compounded concern with forest loss undermining the stability of Brazilian agriculture and ecosystems in the face of climate change.

⁴ If Brazil were to seek climate finance for its mitigation laws, potential complications could arise around whether the mitigation activities would in fact be additional. Some mitigation activities would involve compliance with existing laws. Also, with the rise of bilateral climate mitigation finance (i.e. the Amazon Fund) and subnational agreements like the agreement between the state of California, Acre and Amazonas states, preventing double counting could become a problem. Additionally, to the extent that the NAMAs themselves are interrelated, double counting could also arise.

agricultural drivers of deforestation. LULUCF emissions form the vast bulk of all anthropogenic GHG emissions from Brazil and addressing them may be harmonious with the momentum for UN-REDD, and with the multi-billion dollar Amazon Fund to address longstanding international pressure for Brazil to end deforestation.

In this section we define what we mean by the terms cattle ranching intensification, land sparing and CRIPs.

Defining the terms: intensification, land sparing & CRIPs

Intensification

Cattle ranching intensification is a subset of land use intensification and agricultural intensification. Neither land use intensification nor agricultural intensification are wholly subsets of the conventional notion of industrial intensification employed in production economics. Industrial intensification conventionally refers to the use of more of any production input relative to other inputs per a given quantity of output. By contrast, the concept of land use intensification generally refers to changes in agricultural production practices that lead to more agricultural outputs per area of land input. This most commonly means boosting non-land inputs in ways that boost output. It could also mean an increase in factor productivity through the adoption of a new, more efficient technology. Alternatively, because land quality can vary, agricultural intensification can also mean boosting the quality of the land input by changing the land area farmed through acquisition, sale or swapping.⁵ The former form of land use intensification—changed production practices—is the version of intensification typically envisioned by proponents of CRIPs for land sparing.

Another key consideration is the functional unit used to measure quantities of outputs and inputs. Some analyses consider the financial value of inputs and outputs to be the functional

⁵ Land quality can only vary without the quantity of the land input varying if the quantity of the land input is expressed in area or some other metric independent of quality. Sometimes value of land is the metric for land inputs and in this case land quality would be incorporated. We discuss metrics of inputs and their implications in the next paragraph. The improvement of the existing land would be more conventional intensification that results from an increase in a non-land input.

unit for accounting intensification; other studies use metrics such as physical quantities (Hubacek & Van Den Bergh, 2006). Still other approaches use hybrid and/or inferred measures as functional units. Thus, an increase in the value of the land input could actually be associated with a decrease in the area of the land input under appreciating land prices or a shift towards higher quality land. In the case of cattle ranching systems, intensification can be used to mean anything from a slight increase in intensity of extensive pasture systems to a switch to feedlots from open grazing. Note that in cases of production systems involving supplemental feed, the land used to produce the supplemental feed is not always accounted in the intensity metric.

Land Sparing

The concept of land sparing is based on the theory that agricultural yields over time can reduce the overall area of agriculture lands from what would have been needed without the increase in yields. The land sparing concept has been applied to scales ranging from local to global. The earliest discussion of land sparing centred on the potential for intensification to alleviate and prevent hunger, but the discussion has expanded to also address indirect environmental externalities including deforestation, biodiversity conservation, ecosystem services, and greenhouse gas emissions (Green et al. 2005; Balmford et al. 2005; Matson & Vitousek 2006; Fischer et al. 2008) in general and more recently climate externalities (Burney & Lobell 2010; Rudel et al. 2009; Angelsen 2010; Gouvello 2010).

Cattle Ranching Intensification Programs

Few CRIPs exist yet, but we define them as any sort of intervention with the express intent of reducing GHGs by increasing the intensity of cattle product output per unit pastureland. This can include early stage efforts to trial or pilot solutions. CRIPs comprise direct interventions in the cattle sector like credit, input taxes and subsidies, research & development, and output taxes and subsidies. They also comprise indirect interventions like agricultural infrastructure construction and planning, and even trade and fiscal policies.

CRIPs could take many forms. For example, CRIPs might work by rewarding intensiveness or by penalizing for extensiveness. Yet it is also important to consider the *ex ante* (with regard to the CRIPs) intensification trend. In period zero each ranch might be of average, above average, or below average productivity. In addition, each might be trending flat,

intensifying, or extensifying over the period prior to the subsidy decision. Note that the productivity can be compared to the national averages, but also to regional averages. In this way, benchmark intensification could be absolute or relative to local biophysical and economic conditions.

Premises for CRIPs

In order to assess the viability of CRIPs as a GHG mitigation strategy, we examine both their explicit and implicit premises. For each premise, we examine the logic and the inconsistencies, the potential consequences and the potential remedies.

Premise One: Accelerating Intensification is Straightforward and Measurably Additional

The first premise is that it would be straightforward to accelerate adoption of intensive cattle ranching technologies in Brazil. Because of the large yield gap between many extensive, low output cattle ranches in Brazil and the best performing cattle ranches, a body of literature has emerged arguing that cattle ranching has high potential to boost yields via wider spread adoption of existing technologies (Thornton & Herrero 2010; Cerri et al. 2010; Euclides et al. 2010).⁶ Those that would like to accelerate adoption of intensive technologies suggest that subsidies will be required across rangelands with high logistics costs, degraded or low

⁶ Brazil has regions with high beef production intensity (South and Southeast,) and regions that are primarily extensive (North, Northeast). Several broad categories of ranching practices influence the land productivity of cattle systems (1) intensive pasture management, (2) supplemental feeding, and (3) improved health and sanitation. Intensive pasture management relies on increased use of inputs, capital, and genetic resources during the establishment phase and to some extent during maintenance phases relative to more extensive management. The combination of land grading, liming, and seeding of grasses or grass/legume combinations such as varieties of *Brachiaria* sp. which are heartier and more digestible than native grasses, also requires more labor than traditional pasture management, which relies more heavily on pasture rotation and seasonal burning to control overgrazing, suppress weeds, and restore soil nutrients (Vosti et al. 2001; Angelsen and Kaimowitz 2001; Barros et al. 2002; Euclides et al. 2010). More intensive pasture management may be more labor intensive than traditional pasture management, which relies more heavily on pasture rotation and seasonal burning to control overgrazing, suppress weeds, and restore soil nutrients. Supplemental feeding and improved health and sanitation practices can also improve system productivity and contribute to the success of more land-intensive systems. In contrast to confining cattle to feedlots, supplemental feed can be used to promote weight gain and shorten the life-cycle, to supplement pasture forage during the dry season, or to increase cattle stocking densities (Sampaio et al. 2001). In Brazil, animals are often fed grass, hay, or sugar cane grown on-site if forage becomes scarce, and some ranchers buy similar supplemental feeds. Supplemental feeding of mineral salts (as opposed to simple salt supplements) or salts in which bovines are known to be deficient can also improve animal health and growth rates (Malafaia et al. 2004). Improved health and sanitation practices include the treatment of parasitic infections through periodic de-worming or topical insecticides, as well as vaccination campaigns against diseases such as foot-and-mouth disease, brucellosis, anthrax, and rabies.

productivity soils, and lack of access to capital. The theory is that CRIPs might facilitate more rapid dissemination of intensive technologies.

The central critique of this premise is that because adoption of technologies varies by ranch characteristics and geography, it may be wrong to compare technologies across and even within regions. As a result, it can be hard to prove the additionality of a policy if too little is understood about the broader determinants of the intensity. Here we first theorize the adoption process, then outline some of its ranch level and geographic determinants and conclude with remedies to make measuring and managing adoption easier.

Theoretically, ranchers will adopt intensive practices when their expected future profits less their conversion costs exceed expected future profits of business as usual (see Lubowski 2002 for a model example). The attractiveness of any intensification technology will vary across space, time and ranch characteristics. Variable input and output prices and the ratio of the cost of inputs to the value of outputs will affect producers' choices about what input mix to use in current and future periods, strategic decisions about when to slaughter, and the returns to ranching. The expectation about future input and output prices when combined with any risk or uncertainty about prices will also impact decision-making; stable, high output prices and several years of profit may make a rancher more likely to invest in land or capital to dedicate to ranching, or shift toward more input-intensive types of production. Input and output prices vary at both the local and regional levels and are mediated by supply, demand, infrastructure, physical geography, and regulation. Macro-level, local, and regional characteristics such as labour, land, and credit market conditions, current and expected transport costs, land quality, risk perception, and land use policies influence where and when producers adopt intensive technologies.

Labour & Land

Labour and land markets are important determinants of profitability. Incomplete labour markets or shortage of labour supply (particularly in remote regions) may make producers more likely to choose relatively more land- or capital-intensive types of production.

Competition for land among various uses, such as soybean production, cattle ranching, and sugar cane production, may drive up the land price—and the expectation that competition between land uses may happen at some point in the future and cause land values to appreciate may cause producers to ranch large tracts of land extensively in hopes that the land will be

profitable in some other land use in the future (Hecht 1985; Margulis 2004; Arima et al. 2005; Cattaneo 2008; Walker et al. 2009).

Credit

Credit availability at reasonable interest rates is essential for ranchers to adopt many new technologies, including more productive grass varieties and other types of pasture productivity improvements, or to buy the capital necessary to manage land more intensively (e.g. tractors, fences, etc.). The transition from more land-extensive to more land-intensive forms of ranching requires some combination of increased input usage in the form of fertilizer, lime, grass seed, supplemental feed, mineral salt etc.; upfront investments in machinery; infrastructure and pasture reformation; and increased labour costs. While the returns over the long run to more intensive practices may make their adoption rational, many ranchers and particularly small producers may struggle to obtain credit or access to the necessary financial capital to purchase inputs or machinery. Conversely, cheap or subsidized agricultural credit may encourage ranchers to make larger-than-optimal outlays for land or capital and could result in either greater-than-optimal extent of extensive ranching or intensive ranching, depending upon the confluence of other market characteristics (Margulis 2004).

4.1.3 Transport Costs

Transportation costs underlie ranching profitability because they affect both the cost a rancher pays to get beef and/or dairy products to market (or to pay someone to pick up animals and transport them to slaughterhouses) and the prices of inputs. As such, regions with high transport costs such as remote regions of the Amazon are inherently less profitable for many forms of agriculture, including ranching. This means that reductions in transportation costs, such as the construction of new roads or the paving of existing roads that allow commercial trucks to transport products to and from market even during the height of the rainy season will have important implications for the profitability of different production types and for the adoption of more intensive technologies which are more input-dependent (Arima et al. 2005; Pfaff et al. 2007; Walker et al. 2009; Angelsen 2010). The prior shape and extent of transportation infrastructure can strongly influence how a change in infrastructure influences the competitiveness of different land uses (Pfaff et al. 2007), and changes in transportation costs play an important role in determining land and labour market conditions. Changes in

transportation costs can result in out- or in-migration, and affect the wage rate/opportunity cost of labor (Pfaff et al. 2007). Exogenous increases in transportation infrastructure/decreases in transportation costs will be internalized to land values in the areas affected by the change, thereby causing land rent to accrue to producers in the region.

Policy Context: Property Rights

Policies and enforcement can affect production intensity in numerous nuanced ways. Here, we focus on the role of land tenure and property rights policies and their enforcement. Property rights and or land tenure policies or enforcement might contribute to either under- or over-investment in cattle ranching intensification relative to a case of tenure security (Hecht 1993; Faminow 1997; Angelsen 1999; Araujo et al. 2009). One key determinant of the effect of tenure on intensity is whether tenure is exogenous (independent of any actions of the landowner) or endogenous (produced as a result of some combination of landowner actions), and if endogenous, how landowner behaviours will contribute to tenure security.

Underinvestment in intensification may occur when ranchers are reluctant to adopt risky technologies or make investments on their property as a result of some risk that they will lose their land and associated investments in the future. On the other hand, overinvestment may occur in the case where land tenure is endogenous. In the case of endogenous property rights, investment in intensive technologies or property improvements gives the landowner a stronger claim to the land, either by demonstrating productive use, or by deterring land grabbers. The types and quantities of investments landowners make may increase the probability of retaining the land over the long-run. The use of cattle to establish both *de facto* and *de jure* properties rights over recently-cleared land is an example of a tenure endogenous production technology that may be a major driver of extensive ranching on the Brazilian Amazon frontier (Binswanger 1991; Hecht 1993; Margulis 2004). Wherever clearing one's land is not only essential to obtaining/retaining tenure, but is also insufficient without the use of cattle to maintain the claim, we would expect more extensive land-use relative to a situation where tenure is secure. In such a system, the optimal density of cattle on the

landscape for tenure establishment might be lower or higher than the density to maximize production⁷.

Where questions exist about the performance of an intensification technology, the probability of adoption for the marginal rancher may depend on the frequency of previous adoption. A new technology may be more appealing for a rancher if the rancher's neighbour has already used it and can recommend how much to apply, and can demonstrate increased profitability through its use. A notable implication is that, all else equal, prior adoption may reduce the marginal cost of adoption by lowering risk alone.

Farm Size

Farm size may have several implications for the propensity to adopt intensive technologies. First, we might expect that the optimal farm size for production systems that are more labour-intensive when compared to other systems (e.g. systems that involve dairy) is smaller. Because labour requirements for these systems will vary directly with herd size, even pasture-based dairy systems are likely to be smaller and more intensive than systems that are more focused on beef production. On the other hand, large producers might be more likely to adopt intensive ranching practices if there are increasing returns to scale associated with using particular types of capital or with pasture reformation or feed storage (Angelsen and Kaimowitz 2001; Somwaru and Valdes 2004). Large farms located in regions where the opportunity cost of land is low, however, may be less likely to intensify, particularly if establishment of property rights still occurs through clearing and occupation/productive use (Binswanger 1991; Margulis 2004). Finally, it seems likely that access to credit is tied to existing farm size. If it is true that producers with larger farms and/or significant capital accumulation can more easily gain access to credit, we might expect that large and successful ranchers will be most likely to adopt more intensive technologies before these technologies diffuse to smaller and potentially more risk-averse farmers that are less able obtain agricultural credit.

⁷ For land sparing considerations, land use intensity should be measured as a function of the productive output of a cattle herd and thus the lower the slaughter rate, the lower the intensity of production. If land use intensity is measured as a function of the herd itself lower slaughter rates can increase herd density. The need to use cattle to establish/maintain property rights could discourage slaughter.

Understanding technical adoption patterns across space and ranch characteristics can be improved by conducting randomized control trials to measure the effects on cattle rancher behaviour. Doing this would allow for scientific observations of the propensity of ranchers to adopt management practices and further changes to production systems that could increase or decrease forest pressure. When synthesized with robust technical descriptions of production systems and base ranch and geographic data, a knowledge base could be created that would serve as an essential element to demonstrate the extent of CRIPs impacts and additionality.

Premise Two: Brazilian Pasturelands Have Significant Potential for Alternative Uses

The second major premise is that by occupying a very large area in Brazil, cattle pasture is monopolizing land that could be put to more productive land uses. In 2006, at last count, cattle ranching occupied roughly 200 million hectares of Brazil, more than one fifth of the land surface of Brazil (see IBGE 2010). By contrast, all of crop agriculture in Brazil combined occupies just 62 million hectares (see IBGE 2011).

Since Ricardo (1891) and Von Thunen (1966), land economists have recognized that the quality of land and its isolation from markets can influence its value and its use. With a potential for value to now be placed on land use changes emissions and/or emissions reductions from reforestation, a third consideration should be the unique greenhouse gas value of each piece of land. Such a value could correspond to the greenhouse gas benefits of maintaining an ecosystem and/or the greenhouse gas costs of converting it (Anderson-Teixeira & DeLucia 2010). The relative significance of these three distinguishing characteristics, however, has not been rigorously examined and it is not a typical component of discussions on the fate of Brazil's 200 million hectares of cattle pastures.

One important problem with the premise that each of these hectares is equivalent is that this could lead to overestimates of the production potential of marginal lands. The best remedy is to develop a new functional unit that takes into account land quality, isolation from markets, and greenhouse gas value. Such a functional unit would need to be derived from empirical research.

Premise Three: Reducing Extensive Cattle Ranching Will Have a Substantial Effect on Deforestation Rates

Another motivating premise is that extensive cattle ranching causes a substantial fraction of the deforestation on the land it occupies. Ranching has been identified as strongly correlated with recently deforested lands in Brazil and this has been widely and liberally interpreted to suggest that ranching in fact is the cause of this deforestation (Kaimowitz et al. 2004; Government of Brazil 2004; Wassenaar et al. 2007; Bustamante et al. 2009; Cederberg et al. 2010). In its action plan for prevention of deforestation of the Amazon (2004:10), the Government of Brazil asserts that, “Cattle ranching is responsible for almost 80% of the total deforestation in the legal Amazon.”⁸ In response to the rapid growth of the industry and allegedly associated deforestation and GHG emissions in Brazil, a number of government and non-government initiatives have sought to curb ranching expansion. This includes the Cattle Agreement for traceability to prevent sourcing from recently deforested ranches, the Brazilian government’s embargoed municipalities list, and efforts by several Brazilian public prosecutors to limit credit for cattle sector actors that don’t follow forest laws (Walker et al. 2010). The theory is that CRIPs too can curb ranching expansion.

Other analyses also use correlation and causation interchangeably. Steinfeld et al. (2006) allocate two thirds of all cattle-related land use change (LUC) in the world to “extensive-type” production systems. The authors do not, however, formally define “extensive type” production systems nor do they make an attempt to distinguish within the “extensive type system” category. Moreover, it seems clear that the aggregate livestock LUC emissions estimate Steinfeld et al. (2006) use is based on the estimate by Wassenaar et al. (2007). In Wassenaar the authors clearly state that they have simulated the likely future location of cattle ranching based on biophysical characteristics of current cattle ranching. They then overlay this on a simulation of deforestation conducting using similar criteria. The relationship that they are simulated is correlative, not causal.

⁸ This number most likely comes from an analysis at the census tract level to estimate the proportion of recently deforested land occupied by cattle pasture. See Chomitz & Thomas 2001. A forthcoming study finds that in 2010 ranching occupied 62% of deforested land in the Amazon biome. See Bitencourt 2011.

Another approach is employed by Cederberg et al. (2010). They “present a model to distribute emissions from land use change over [cattle] products...” produced in the Brazilian Amazon. The Cederberg team first uses a land use change Markov model developed by Fearnside (1996) and presented in Ramankutty et al. (2007) to estimate the deforestation emissions that they attribute to all Brazilian cattle ranching. They use an estimate of the proportion of deforested land in Brazilian Amazon eventually occupied by pasture in the “final land use stabilized after ~50 years i.e. the equilibrium state”. Since the Markov land transition model on which the study is based imputes no causality it follows that the Cederberg paper concludes with a discussion on the “beef [that] should carry the burden of the emissions.” In this portion of the paper they describe three options, beef from recently deforested land in the Amazon, all beef from the Amazon, and all beef from Brazil. They do not, however, suggest which of these options makes the most sense.

Cattle ranching is a cause and perhaps it is even the largest cause of Brazilian deforestation. Some of this deforestation includes some or all of the forest lost at the location of the cattle ranching itself. Interventions that reduce the area of ranching in Brazil could directly and/or indirectly reduce the amount of deforestation in Brazil. It is not necessarily true, however, that avoided deforestation would occur where the ranching is lost or in proportion to the area of ranching lost. The management practices of each ranch, its agronomic resource endowments, its isolation from markets and its market and regulatory context will affect the net influence of the ranch on agricultural extent and forest cover.

For this reason, it is crucial to base policy in a strong understanding of the relationship between forests and extensive livestock. The consequences of not doing this could be to overestimate the GHG benefits from reducing extensive ranching extent. This is because if extensive ranching is not causing all the deforestation it is occupying, reducing extent of extensive ranching might not create a corresponding decrease in deforestation.

Since the drivers of deforestation are global, it is not possible to use replicates to control for the effects on forests of programs to reduce extensive ranching. Therefore, the best remedy for this problem is to improve land use change models by incorporating understanding of the technical and socioeconomic characteristics, and the regulatory and market contexts of cattle ranching. These data are of the sort to be collected to remedy problems one and two.

Premise Four: Increasing Intensive Ranching Will Reduce Extensive Cattle Ranching

A corollary of the premise that extensive cattle ranching has caused the deforestation on the land that it occupies is that if higher intensity cattle ranching were to replace extensively-produced cattle products that this would reduce deforestation. This could hold true in certain special cases like sufficiently small markets far where ranchers do not spend increased profits on increased frontier settlement. In such places, the increase in supply could reduce cattle product prices enough to reduce pressure on forests sufficiently so that the deforestation associated with an increase in profits is small in relative terms (Kaimowitz & Angelsen 2008).

However, even in small markets, investments in settlement could lead to more deforestation than land savings from reduced beef prices. Moreover especially in time of economic instability, substantially depressed beef prices are not always sufficient to encourage pasture investment (Kaimowitz & Angelsen, 2008). The market could be sufficiently large that increased production could have a negligible effect on cattle product prices and therefore have little effect on the quantity of profitable extensive ranching. In many other cases, increased intensive cattle ranching would be unlikely to decrease extensive ranching because ulterior motives for extensive ranching drive extensive ranching and not necessarily the sale of cattle products. Extensive ranchers hold land not only to produce cattle but also to speculate, secure land tenure and receive government subsidies (Kaimowitz & Angelsen 2008).

Premise Five: Boosting Intensity Will Actually Spare Land (and not just encourage more consumption)

Supporting CRIPs means assuming that demand for cattle products is sufficiently inelastic such that when yields increase areas will decrease to spare land. Inelastic demand may apply to staples and to food in aggregate. In this way, higher efficiency food production may escape Jevon's Paradox—i.e. the circumstance where the more efficient the production process of goods with elastic demand becomes, the more demand arises for the goods (Alcott 2005).

Demand for beef might be quite price elastic (Andreyeva et al. 2010). The central tendency of an increase in the share of food from beef would be substantial increases in GHG emissions

from food consumption.⁹ The best solution to the problem would be to design CRIPs such that they do not lead to lower prices. Perhaps they could aim to keep both rancher profits stable and consumer prices for beef at equal or higher levels.

Premise Six: Increased Intensity Has Social and Environmental Co-Benefits

A fundamental premise for promoting CRIPs is that unintended environmental and social costs of the program do not exceed the benefits gained from GHG mitigation.

Non-Climate Environmental Effects of CRIPs

For the most part, the literature on agricultural intensification and the environment is clear that the environmental track record of intensification is mixed- without care agricultural intensification tends towards a loss of local environmental quality, but the increased output may have substantial indirect benefits including land sparing. The good news is that there is not a direct link between a change in the intensity of production and environmental costs or benefits- opportunities for environmentally friendly intensification exist (Matson et al. 1997; Tscharnke et al. 2005). That said, more serious environmental trouble has arisen with the increase of industrial livestock production (Naylor et al. 2005). Water use and pollution are especially pressing and costly problems and their effects are magnified in regions with poor environmental governance. With the exception of the United States and Europe, the cattle sector has not seen the same levels of industrialization as other livestock sectors.

Social Effects of CRIPs

At the country level, some argue that agricultural intensification may be a necessary but not sufficient condition for development. Yet to get a better handle on when and how agriculture contributes to development more empirical research is necessary, and/or modelling that does a better at incorporating non-linear systems, threshold effects and the like (Lee & Barrett 2001).

⁹ Further research is needed on the contribution to land use change of an addition or subtraction of a marginal unit of livestock products. Such analysis depends on the extent to which land were functionally equivalent to produce beef and other feed products. To the extent that land is suitable for use as either rangeland or cropland beef and other ruminant meat would be by far most climate intensive food product by a long shot. Meat of monogastrics and other livestock products would much better than beef, but somewhat worse than vegetable products (Weber & Matthews 2008). To the extent that beef is produced on land unsuitable for other livestock and agricultural production, perhaps this hierarchy changes. Further research is needed on the contributions to the suitability of land attributes such as yield potential, governance, and levels of market access.

Perhaps such work could help to elucidate the costs and benefits of intensification of one crop vs. that of another.

When we consider the social welfare implications of CRIPs, it is important to consider several key factors: the existing policy landscape, the dynamics of the adoption process associated with more intensive technologies, the costs, benefits, and externalities associated with ranching and other competing land uses, and the relative cost-effectiveness of ranching intensification as a GHG mitigation strategy. Whether future intensification or policies designed to encourage intensification result in welfare gains or losses depends on the broader land use policy landscape (Zilberman et al. 1991). For example, productivity improvements (and the resulting shift in supply) in ranching could be social-welfare-improving if the government subsidizes producers via credit programs, but it depends on the opportunity cost of the subsidy. Conversely, there may be a net social welfare loss (through price pass through to consumers) in the absence of government interventions, but this could be offset by the opportunity for government spending on other more socially beneficial things.

With regard to the patterns of adoption of more intensive cattle ranching practices, it is important to think about how patterns in who adopts and when could result in welfare gains or losses for particular types of producers, and whether these gains or losses might change over time. Because adoption of intensification technologies may require up-front capital investments and potentially exhibit economies of scale, we might expect that larger, wealthier producers would lead in adopting technologies more quickly. This trend, however, might result in some learning-by-doing for smaller or less-wealthy producers as well as reduced cost of implementation of the technologies for intensified production, but cause them to lag behind larger producers in adopting. This would result in potential welfare improvements for different types of producers at different points in the adoption process. If larger producers adopt first, there is also the potential for concentration of landholdings, however, as larger producers accumulate capital more quickly and take advantage of any economies of scale that might not be available to smaller landholders.

Premise Seven: Marginal Abatement Costs for CRIPs Are Much Lower than the Benefits

Perhaps the most important premise of CRIPs is that they could deliver large-scale low cost GHG abatement. We saved this discussion for the end because it touches on all aspects of the

paper. In its NAMAs, Brazil has pledged for the years 2010-2030, over 1 billion tons in CRIPs-centered GHG mitigation activities worth roughly \$20 billion¹⁰, but at an abatement cost estimated to be closer to \$3 billion in private costs to cattle ranchers (Gouvello 2010). Yet in this paper we have described how for CRIPs to be well designed and executed, additional costs will arise in order to close crucial data and science gaps required for good land use governance in Brazil. If CRIPs were to deliver 1 billion tons of CO₂e of mitigation, the scale of the potential risks and opportunities for CRIPs would nonetheless warrant a substantial investment by buyers and/or sellers to verify the carbon value that CRIPs could generate. Here we make a rough estimate of costs associated primarily with closing key data gaps. We presume that closing some key parts of science gap could closely and relatively cheaply follow.

Understanding of the CRIPs context could improve from better monitoring of the area, productive capacity and use of pasturelands. In the past Brazil has accounted pasture area only once a decade as part of the national agricultural census. If area were accounted with greater frequency- perhaps annually—it would substantially improve understanding of the drivers of pasture use changes. The agricultural census is expensive to conduct. The entirety of the last agricultural census cost roughly \$250 million (Oliveira et al. 2006). At that price, annual estimates of pasture area would be a maximum of \$5 billion until 2030—less than the purported mitigation benefits of CRIPs, but nearly tripling CRIPs estimated marginal abatement costs by themselves.

Much cheaper alternatives may exist however. On September 6, 2011, The Brazilian Space Agency (INPE) was set to release data from the first iteration of TerraClass, a collaboration between INPE and Embrapa to classify land use occupying recently deforested land in the Legal Amazon—2/3 of the country. Endowed with roughly \$400 million dollars by the Brazilian government and a consortium of Northern nations, TerraClass is intended to map land cover including pasture each year. TerraClass is able to leverage PRODES, a \$1 million per year system to monitor deforestation in the Legal Amazon (G1 News Brazil 2011; Bitencourt 2011; Brazilian Ministry of Science & Technology 2011). Even if we assume that extending TerraClass to the entire country would require extending PRODES-style satellite

¹⁰ At August 2011 EU ETS carbon prices retrieved from pointcarbon.com

monitoring to whole country, monitoring of pasture area during the NAMAs period could cost as little as \$880 million total. Moreover, since the systems leverages remote sensing, perhaps it would be reasonable to also develop assessments on the productivity of pasturelands. Knowing productivity potentials could be helpful to identify land-conserving management practices and establish performance metrics for CRIPs.

An excellent complement to improved monitoring of area and quality of pastureland would be to monitor the location and movements of the national cattle herd. Traceable radio frequency identifier chips are already implanted in some cattle in Brazil to prevent sourcing from illegally deforested lands. Traceability could also greatly aid measurements of cattle ranching productivity. Baseline levels of productivity are, in turn, critical to estimate the extent of intensification a CRIP causes. Early experience from the cattle industry indicates that traceability can be expensive. While the hardware costs \$4/animal life, one industry source estimates total private costs of approximately \$30/animal life (Dias Lopes 2011). Since animal lives are roughly three years this would mean costs of roughly \$10/animal/year. For 200 million animals over 20 years this would mean \$40 billion in private costs of tracing cattle. Private traceability initiatives are prone to fraud and so government enforcement would be needed. This too could be substantial. Cattle ranches cover one quarter of Brazil's land area and enforcement in these areas has been lax. If it has been zero and enforcement varies with area, this could increase the budget for environmental enforcement in the country by 25% or roughly \$500 million dollars per year (Senate of Brazil 2010). Thus in all, traceability could cost \$50 billion dollars over the course of mitigation period. This is an untenably high figure. Its cost would need to come down 10 fold in order to enter the feasible range. Streamlining seems a reasonable expectation. If instead of a census a random sampling approach were employed cost savings could be dramatic.

In addition to higher-than-advertised costs, CRIPs could have lower than advertised GHG mitigation since verifying benefits would require further data, science, and regulation to resolve. To be fair this sort of critique can be raised for the early stages of many climate policies. Thus, it would be perfectly reasonable for CRIPs to begin with trials to improve the science of agricultural technology adoption and ultimately the potential to manage GHG emissions from the Brazilian cattle sector.

Conclusion

If Brazil wants to address its climate emissions, like many Southern countries it must address emissions from land use. These dominate all anthropogenic emissions. Given its large area, cattle ranching will surely play a role in future of land use and hence climate policy. For this reason and the many premises we outline, CRIPs have become central to discussions on strategies to address agricultural drivers of deforestation and develop climate-friendly biofuels policies. As we have demonstrated, however, a number of these premises could lead to unintended climate costs from some CRIPs approaches. For now, it is best to proceed cautiously with CRIPs, to begin by collecting data on cattle systems and to develop trials to build scientific understanding of rancher technology adoption. Even with better science and data, the viability of CRIPs for climate mitigation will be contingent on factors beyond the cattle sector like forest governance, and beyond Brazil's borders like global demand for cattle products. In the meanwhile using CRIPs to close data and science gaps can pay dividends by enabling management of cattle ranching for broader social and environmental benefits even if CRIPs for climate mitigation do not materialize.

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