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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 the production of more biofuels and other agricultural products. 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: intensive cattle ranching technologies are already in commercial use; accelerating adoption is straightforward; increasing intensive ranching can reduce cattle product prices; reducing cattle product prices can reduce pasture area; reducing extensive cattle ranching in Brazil can deliver GHG benefits; CRIPs will deliver environmental & social benefits; and that the GHG benefits from CRIPs will exceed implementation costs. We argue for CRIPs trials as part of a broader effort to reduce several key data and science gaps crucial for assessing the impacts 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.

About the authors

Avery Simon Cohn (corresponding author)

Department of Environmental Science, Policy, & Management

University of California Berkeley

130 Mulford Hall 3114

Berkeley California, 94720-3114 USA

avery.cohn@gmail.com

Maria S. Bowman

Department of Agricultural and Resource Economics

University of California, Berkeley

David Zilberman

Department of Agricultural and Resource Economics

University of California, Berkeley

Kate O'Neill

Department of Environmental Science, Policy, & Management

University of California Berkeley

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Contents

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 (REDD). One proposal is land sparing, the concept of boosting outputs from agricultural lands and/or steering agricultural expansion onto low carbon content lands 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 quantity of cattle product output per unit of 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; Searchinger & Amaral 2009; Embassy of Brazil 2010; Gouvello 2010; Angelsen 2010; Boucher et al. 2011; Amend et al. 2011; Ecofys 2011; Pinjuv 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).[1]

As part of eleven billion tons of potential GHG mitigation between 2010 and 2030, Brazil's NAMAs pledge roughly one billion tons of annual climate mitigation during the year 2020.[2] The NAMAs commit just 10% of total mitigation to come directly from changes in cattle ranching practices. However, we estimate that roughly 90% of the mitigation proposed would

[1] 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 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.

[2] The NAMAs letter details reduction potential in the year 2020 alone, but our analysis suggests that the pledge is a cross section of a mitigation path for the period 2010-2030 that corresponds with Brazil's 2010 Climate Law. In subsequent paragraphs we describe this mitigation path as detailed in a World Bank report closely related to the NAMAs pledge (Gouvello 2010).

come from reduced land use change and changes in output and production practices in agricultural systems that could hinge on increased cattle ranching productivity[3]. As the report detailing the NAMAs describes it, "Increasing …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" (Gouvello 2010:28).

The ranching focus of Brazil's NAMAs may emerge from a typical, but questionably accurate model representation of cattle ranching systems in a World Bank report closely linked to NAMAs.[4] To depict GHG-reducing CRIPs, the World Bank team imposes a constraint on the total area of land available for use as pasture in Brazil and caps total Brazilian livestock and agricultural output at reference levels. By imposing the land constraint, the team "frees" land in the simulation for forests and crops. Together, the two constraints cause the simulation of substantially lower GHG emissions in the low carbon scenario than in the reference scenario.

The simulation demonstrates the greenhouse gas mitigation potential of cattle ranching intensification in Brazil under these model constraints, but it is unclear how to design interventions to elicit analogous effects in practice. We take up this question of CRIPs design via a literature review. We first define key terms used in our analysis and then present premises, both explicit and implicit, that underlie the mental and mathematical models that suggest CRIPs as promising GHG mitigation strategies. We close by describing activities that should begin now to advance the potential for CRIPs to be an effective GHG mitigation strategy.

[3] 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 clearly stating 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 [crop] 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. Beef-cattle farming shows much greater potential for increasing productivity 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."

[4] 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).

Table 1 Brazil's Proposed NAMAs: Pledged Emissions Reductions for the year 2020

	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 *cerrado* deforestation	104	10%-11%
No-till farming	16-20	2%
Biological N_2O fixation	16-20	2%
Biofuels use	48-60	5%-6%
Total ranching related	*748-768*	*74%-77%*
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

Defining the terms: Intensification, Land Sparing & CRIPs

In this section we define the terms cattle ranching intensification, land sparing and 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 is the use of more of any production input relative to other inputs per a given quantity of output. By contrast, 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 new, more efficient technologies. 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.

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

[5] The role agricultural land quality in the expression of agricultural inputs and outputs is actually quite complex and variant. Some analyses consider the financial value of inputs and outputs to be the functional unit for accounting production; other studies use physical quantities and others use hybrid and/or inferred measures (Hubacek & Van Den Bergh, 2006). 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. Land quality can 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. When land price is the metric for land inputs then the quantity of land inputs would vary with both land quantity and land quality. Note also that changes to land quality can result from excessive or insufficient use of other non-land inputs.

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 aggregate increases in agricultural yields over time can reduce the overall area of agriculture lands from what would have been needed without the increase in yields. These increases could occur through either the use of degraded, marginal, and abandoned lands or through increases in yields on lands currently in cultivation. 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, (Green et al. 2005; Balmford et al. 2005; Matson & Vitousek 2006; Fischer et al. 2008) and more recently GHG emissions (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 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. By definition CRIPs seek to alter the 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 CRIPs. 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.

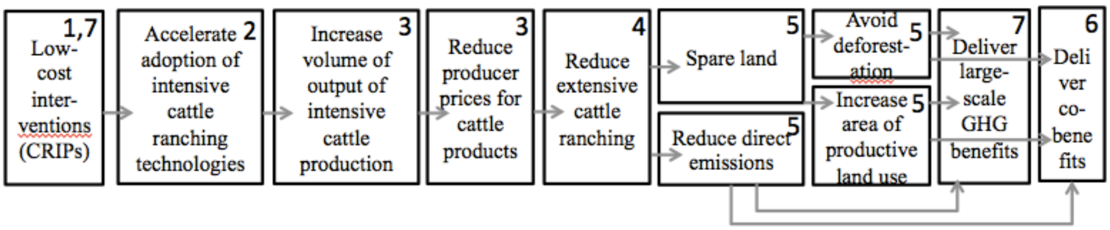
Seven Premises on Which the Efficacy of CRIPs Depends

The conceptual model underlying CRIPs is more complex than the literature sometimes suggests. The Gouvello (2010:27) report, for example, explains the CRIPs concept this way:

> [CRIPs] 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.

This seems to suggest that GHG mitigation = (original area needed - original area needed/yield improvement index) * average GHG savings per area of land spared.

Figure 1: One CRIPs Conceptual Model



This figure details one conceptual model for CRIPs as a GHG mitigation strategy. We introduce the model components and their plausibility in depth in the following section. We organize this discussion around examination of seven crucial premises on which the CRIPs conceptual model is contingent: 1) Intensive Cattle Ranching Technologies are Already in Commercial Use 2) Accelerating Adoption is Straightforward 3) Increasing Intensive Ranching Can Reduce Cattle Product Prices 4) Reducing Cattle Product Prices Can Reduce Pasture Area 5) Reducing Extensive Cattle Ranching in Brazil Can Deliver GHG Benefits 6) CRIPs Will Deliver Environmental & Social Benefits 7) The GHG Benefits From CRIPs Will Exceed Implementation Costs . The number in the upper right corner of each box in the figure indicates the "premises" section where we discuss the contents of that box.

The CRIPs concept depends on essential, but not always mentioned, intermediate steps on the path from productivity increases to GHG mitigation. Figure One depicts what we consider the key components of one popular CRIPs concept.[6] If land sparing is to be mitigation then it must consist of a reduction in land use area relative to business as usual land use area for a given level of production and this must come from increased productivity. By definition the

[6] By definition CRIPs work to increase the aggregate intensity of cattle ranching systems. This can occur via command and control or market intervention. If market interventions, CRIPs would entail increasing the competiveness of intensively produced cattle products relative to extensively produced cattle products. This could occur either by interventions to cheapen intensive production systems or interventions to make extensive systems more expensive. The former model has been much more frequently discussed and so it is the concept on which we focus our analysis.

"increased productivity" must be sparked by some intervention without which it would not have otherwise occurred. It cannot have been increased productivity that would have happened anyway. Next there is the matter of "absorbing the expansion". This requires something like a market that conveys the impacts of the increased productivity production systems on the business as usual production systems. In this case, the market is for the products of both the intensive and extensive systems types. Therein the increased productivity systems must outcompete the business as usual systems on cost and thus reduce overall prices. These price are intended to lead to a reduction in the demand for cattle ranching land by reducing the area of land over which ranching is profitable. This reduction, then "spares" land for other uses including the conservation of natural vegetation and crop agriculture. A subset of this crop agriculture could then be biofuels that under some circumstances could deliver further GHG benefits via displacement of fossil fuel. The shift from intensive to extensive ranching should also contribute to reduction in the direct GHGs associated with the cattle sector. The direct and indirect GHG benefit together would then need to exceed GHG costs of these changes, including potential soil carbon flux from LUC caused and potential increases in direct agricultural and land use change emissions due to increased cattle product consumption under lower cattle product prices. Finally, these net CRIPs GHG benefits would need to be worth the implementation costs.

In this section we explore the components and the plausibility of the CRIPs conceptual model by examining five crucial premises on which the model is contingent: 1) Intensive Cattle Ranching Technologies are Already in Commercial Use 2) Accelerating Adoption is Straightforward 3) Increasing Intensive Ranching Can Reduce Cattle Product Prices 4) Reducing Cattle Product Prices Can Reduce Pasture Area 5) Reducing Extensive Cattle Ranching in Brazil Can Deliver GHG Benefits 6) CRIPs Will Deliver Environmental & Social Benefits 7) The GHG Benefits From CRIPs Will Exceed Implementation Costs. We examine the strengths and weaknesses of each premise, we highlight reasons for concern and optimism, and we identify opportunities to improve the likelihood that CRIPs deliver GHG benefits.

Premise One: Intensive Ranching Technologies are Already in Commercial Use

An initial premise for CRIPs is the existence across Brazil of pockets of "proven and mature" cattle production technologies that offer substantially lower direct emissions and higher land intensity and than typical production systems (Pinjuv, 2011).

Improved diets, genetics, and management can reduce enteric fermentation per unit feed consumed and per unit weight gained (Thornton & Herrero, 2010). Together these combine to reduce methane emissions from enteric fermentation per unit cattle product. In semi-industrialized systems, waste management can also be a means to reduce nitrous oxide and methane emissions. Over the past decade, the average lifespan of Brazilian cattle, a key indicator of direct emissions, has dropped significantly (Association of Brazilian Beef Exporters, 2011). However, the aggregate decline is not due to uniform efficiency gains in the industry, but rather a vanguard of advanced regions (Gouvello, 2010). The hope is that other regions could now follow suit.

Increases in land intensity if associated with proportional decreases in deforestation, have the potential to be a much bigger source of mitigation from ranching than reductions in direct emissions (Cederberg et al. 2010). Widespread adoption of numerous land use intensification strategies can be found across Brazil. 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; 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.

Critiques of this premise center around the limitations of productivities per unit area as a metric for the GHG performance of any given cattle ranch. We expect, for example that yields will vary according to climate, biophysical constraints and socio-economic factors relating to the farm and its location. Short-run anomalies could arise from climatic and economic variation and longer-run anomalies could arise from the ability of ranchers to improve or worsen their lands and also as the socio-economic circumstances of each ranch changes. Therefore questions emerge about whether intensities are best expressed in absolute terms or relative to some local and/or ranch specific benchmarks. Research is needed to develop CRIPs-relevant cattle production intensity performance metrics. Finally, as described in our conceptual model, markets mediate the relationship between interventions in cattle ranching intensification and GHG mitigation and this adds an additional layer of complexity. We address these issues in the following premises.

Premise Two: Accelerating Intensification is Straightforward

A body of literature has emerged arguing that relatively cheap investments could accelerate the adoption of a suite of proven and reasonably widespread cattle ranching technologies (Thornton & Herrero 2010; Cerri et al. 2010; Euclides et al. 2010). Even though the technologies are already preferred on some ranches, proponents argue that investments are needed to offset high logistics costs, degraded or low 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 *ex ante* intensity trend. 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).

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 competiveness 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 production[7].

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 Three: Increasing Intensive Ranching Can Reduce Cattle Product Prices

The third premise underlying the CRIPs concept is that interventions that cause increased production of intensively produced cattle products can reduce the cattle product producer prices germane to the extensive cattle industry of Brazil. For this to be true, there must be a linkage between markets for the intensive and extensive cattle products. Until quite recently, large isolated markets persisted in the North and Center West of Brazil. Now infrastructure improvements have greatly increased market interconnectivity across Brazil (Faminow 1997; Association of Brazilian Beef Exporters 2011). Some barriers to market integration do still remain. Some areas of Brazil are still not able to participate in export-oriented markets. They are inhibited for a variety of reasons. For example, they may lack certification demonstrating that they are free of hoof and mouth disease or they may lack the ability to demonstrate that the full supply chain complies with forest laws. As Brazil's beef exports rise, we should assess the market for Brazilian beef as part of a global beef market of increasing size. Given this scale, the extent of price effects in Brazil from an increase of intensive beef in Brazil could be dampened.[8] The formation of livestock prices under an intensification intervention could depend on a number of indirect effects driven by associated inputs prices such as both fertilizer and land. Such indirect price effects could both magnify and dampen the price effects of increased output for intensive cattle systems. Research to quantify the price effects of increased intensive output should be a part of CRIPs pilot projects.

[8] As a result, changes in Brazilian cattle ranching could affect ranching systems in other nations too. These effects might deliver climate benefits that would be difficult to incorporate in some climate policy frameworks.

Premise Four: Reducing Cattle Product Prices Can Reduce Pasture Area

The fourth premise is that a decline in germane cattle product prices could reduce the area of Brazil over which extensive ranching is profitable. The mechanism would be that the increase in supply could reduce cattle product prices enough that for some meaningful fraction of extensive cattle ranches, revenues would no longer exceed costs (Kaimowitz & Angelsen 2008). Over time the reduction could take the form of both a reduction in the expansion of extensive cattle ranching and the abandonment of existing extensive areas. This premise could hold true in sufficiently small markets where a small intervention could have a meaningful price effect or in large markets where a sufficiently large intervention is undertaken.

The activities of land users at the Brazilian forest frontier cannot be explained by agricultural profit maximization alone. First timber and non-timber forest products can be important sources of household income. Second, not all frontier actors are profit maximizers, some may seek to maximize utility in ways such that they do not maximize profit. If it were leisure, higher production prices would mean greater profitability per unit area and a decline in the area required to satisfy the leisure objective (Angelsen & Kaimowitz, 2001). Of even greater salience, however, is ample evidence suggesting that Brazilian ranchers hold land not only to produce cattle products, but also to secure tenure, obtain access to government subsidies, and to speculate on increases in land values (Kaimowitz & Angelsen, 2008). Each of these considerations could dampen the extent that cattle product price declines lead to declining area of extensive ranching.

A further consideration is extent to which demand for cattle products varies as prices vary. If a price decline leads to an increase in demand, this too would dampen the land-sparing phenomenon. Of note is not only the own price elasticity of demand, but also cross price elasticities of consumption substitutes. Supporting CRIPs means assuming that demand for cattle products is sufficiently inelastic such that when yields increase, areas will decrease enough 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 however (Andreyeva et al. 2010). Also, 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 two pronged: research the relationship between cattle product prices and ranching extent, and in the meanwhile design corrective taxes such that CRIPs to keep consumer prices for beef at equal or higher levels.

Premise Five: Reducing Extensive Cattle Ranching Can Deliver GHG Benefits

The fifth premise is that reduced extensive cattle ranching can have three effects relative to business as usual- reduce direct emissions, avoided deforestation and land spared for other productive uses.

Reduced Direct Emissions

As we mention in Premise One, if a unit of beef is produced using the semi-intensive technologies available in Brazil it is most likely that these emissions will be measurably less than emissions from typical extensive production. If land is in fact spared, questions do arise, however, about the soil carbon that could be lost in the conversion from pasture to cropland (Fargione et al 2008).

Avoided Deforestation

Another part of the premise hinges on the idea that extensive cattle ranching is the cause of a substantial fraction of the deforestation on the land that it occupies and, as result, reduced

[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. 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.

extensive ranching would reduce deforestation. 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."[10] 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.

Perhaps the best know study on the environmental impacts of livestock also presumes correlation of pasture and recently deforested land indicates that the pasture has caused the deforestation. Steinfeld et al. (2006) base their estimate of aggregate LUC emissions caused by livestock on 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. As Wassenaar et al. (2007) explain, the relationship that they simulate is correlative, not causal.

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

[10] 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 ranching occupies 62%of the area deforested in the Brazilian portion of the Amazon Biome over the period 2007-2010. See Bitencourt 2011.

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, it 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. One consequence of not doing this could be to overestimate the GHG benefits from reducing extensive ranching extent. This is because if extensive ranching in general and in particular demand for extensively ranched cattle products 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.

Increased Productive Uses

The third portion of this 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).

Ricardo (1891) and Von Thunen (1966), theorize that the quality of land and its isolation from markets can influence it 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 for CRIPs would thus be the GHG value of each piece of land. Such a value could correspond to the GHG 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. For CRIPs, research is needed to develop a new functional unit for land that takes into account land quality, isolation from markets, and GHG value.

Premise Six: CRIPs Will Deliver Environmental & Social Benefits

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

Non-Climate Environmental Effects of CRIPs

The environmental benefits of agricultural intensification are of debated size because it can be difficult to compare local loss of environmental quality with global land sparing. Serious environmental impacts are associated with a number of forms of agricultural intensification and in particular with 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. Intensification need not be associated with more local environmental costs, however. Opportunities for environmentally friendly intensification exist, suggesting that under some circumstances local environmental quality vs. global land sparing is a false choice (Matson et al. 1997; Tscharnke et al. 2005).

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 more specifically examine when and how agriculture contributes to development, more empirical research is necessary, and/or modeling that better incorporates non-linear systems, threshold effects and other complex aspects of the problem (Lee & Barrett 2001). Perhaps such work could help to identify priority intensification opportunities.

When we consider the distributional 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.

Adoption of intensification technologies may require up-front capital investments and potentially exhibit economies of scale so wealthier producers might more quickly adopt intensification technologies. This trend, however, might result in a reduced cost of implementation of the technologies for intensified production and some learning-by-doing for smaller or less-wealthy producers. Smaller producers might still adopt, but lag behind larger producers. 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: The Value of GHG Benefits From CRIPs Will Exceed the Costs

Perhaps the most important premise of CRIPs is that they could deliver large-scale GHG abatement at less than the cost of implementation and less than the costs of many mitigation alternatives. In its NAMAs, Brazil has pledged for the years 2010-2030, over 7 billion tons in CRIPs-centered GHG mitigation activities worth roughly $140 billion[11], but at an abatement cost estimated to be closer to $100 billion in private costs (Gouvello 2010). Yet 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 7 billion tons of CO_2e 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 also list a number of other science and data gaps of uncertain costs.

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 10% of the purported mitigation benefits of CRIPs.

Much cheaper alternatives may exist however. In Fall 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 the roughly 70 million hectares of recently deforested land in the Legal Amazon. 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

[11] At August 2011 EU ETS carbon prices retrieved from pointcarbon.com

per year system to monitor deforestation across the 320 million hectares of 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 monitoring to whole country, monitoring of pasture area during the NAMAs period could cost as little as $1 billion 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 enforcement up until now and if enforcement varies with area, this could increase the budget for environmental enforcement in the country by 25% or roughly $500 million annually (Senate of Brazil 2010). Thus in all, cattle traceability could cost $50 billion dollars over the course of mitigation period. This is an untenably high figure as it comprises a 50% increases in CRIPs implementation costs and would mean that CRIPs costs would exceed CRIPs benefits. Its cost would need to be reduced by a half 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.

The GHG impacts of CRIPs cannot be directly measured because they intend to impact global land cover and there is therefore no way to control for other influences on land use change.

However, better modeling of the GHG benefits could be accomplished through further data, and science. We specify a number of research and agricultural statistics priorities in this section and at the end of each of the first six premise sections. Publicly-available, spatially-explicit agricultural input and output price data, scientific data on the propensity of adoption of intensive practices and data on the influence of environmental regulations on production practices would all be essential to parameterize a model of CRIPs impacts on GHGs. A great deal of this data collection would be best accomplished by designing the early stages of CRIPs as randomized control trials. This would be the most straightforward way to improve the science of agricultural technology adoption and ultimately the potential to manage GHG emissions from the Brazilian cattle sector.

Conclusion

For Brazil to reduce its climate emissions, like many Southern countries it must reduce 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 not only as preparation for CRIPs, but also by enabling better management of cattle ranching for broader social and environmental benefits.

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