POLICY PERSPECTIVES

The coupling of South American soybean and cattle production frontiers: new challenges for conservation policy and land change science

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Abstract

Different drivers and places of land use change in South America have often been studied in isolation. Evidence suggests, however, that in many instances, both places and drivers are becoming increasingly interconnected. The growing diversification and internationalization of agricultural commodity chains is creating new linkages across production frontiers and sectors that have important implications for conservation. In this article, we explore the implications of the sectoral and geographical coupling of soybean and cattle production frontiers for forest conservation in South America, with particular attention to the potential for policy-induced deforestation leakage. We conclude that the existence of coupled frontiers creates a need for more actor-centered approaches to conservation policy and research.

Introduction

Deforestation is one of the main concerns for the future of the environment in South America (hereafter SA). The rise of global food demand and the position of SA as a key provider have promoted the expansion of commodity production into forests, affecting not only the Amazon, but also dry forests and woodlands in Bolivia, Paraguay, and Argentina (Aide *et al*. 2013; Hansen *et al*. 2013). Although there are several studies on specific aspects of this situation, the design of effective conservation strategies requires better analysis and conceptual framing of the general processes at work.

Early work on the emergence of soybeans as a proximate driver of deforestation indicated changes in deforestation patterns (Morton *et al*. 2006) and new opportunities for conservation (Nepstad *et al*. 2006). Recent research has discussed the respective roles of soybean cultivation and cattle ranching in Amazon deforestation, and asked whether soybean expansion over pastures represents land use intensification (Macedo *et al*. 2012) or displacement[1] (Barona *et al*. 2010; Arima *et al*. 2011). These studies implicitly conceive of soybeans and cattle as independent drivers competing for forest land either directly (Morton *et al*. 2006), or through a sequence of displacement (Arima *et al*. 2011). However, evidence suggests that a process of geographical and sectoral coupling has been taking place in the soybean and cattle sectors in SA that has important implications for conservation.

Strong integration of value chains has already taken place in the agricultural sector for commodities such as bananas, coffee, and palm oil (Byerlee 2013), as well as in others primary sectors like forestry and fishing. Companies facing global competition have used integration strategies to capture economies of scale (increasing size) and of scope (incorporating products that share inputs, markets, and know-how). In the case of grain and beef production, horizontal and vertical integration have been common for processing industries and retailers, and are increasingly witnessed in primary production as well.

As linkages intensify between soybean and cattle production, the two sectors increasingly share driving forces

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and actors. Simultaneously, as a consequence of the geographic diversification of agribusiness companies and of the growing prominence of Chinese demand, agricultural production frontiers are becoming more connected through flows of technology, information, and capital, both directly and through third parties. Considering this, we argue that soybean- and cattle-induced deforestation in different locations, rather than being viewed in isolation, should be seen as particular manifestations of one same regional process.

In this essay, we propose a conceptual framework for coupled soybean and cattle production frontiers, and explore its implications for conservation policy, providing evidence from SA. We argue that the existence of coupled production frontiers creates a need for the conservation and research communities to incorporate new points of view and methodological approaches in the design and evaluation of conservation policies.

The coupling of production frontiers

Two aspects of coupling are relevant to our discussion. The first is the *development of coupled driver systems*. Coupled driver systems are sets of linked drivers that jointly produce an outcome in terms of land use changes that is more than the sum of the effects of independent drivers. This in our case would be the system formed by soybean farming and cattle ranching, the impacts of which thus need to be interpreted considering both production sectors and their material, capital, and information linkages. The second aspect is the *telecoupling of production frontiers*, or the transition from a state in which production frontiers in different places function with endogenous drivers and actors to one in which their functioning is integrated through material, capital, and information flows. The concept of telecoupling refers to "socioeconomic and environmental interactions between coupled human and natural systems over distances" (Liu *et al*. 2013), the coupled systems in our case being production frontiers.

Soybean and cattle as a coupled driver system

The soybean and cattle production sectors are traditionally envisioned as independent and competing. We propose that to a large extent, they actually act as complementary parts of one same system (Figure 1, panel A). The ways in which they do so, however, vary, as does their relationship to deforestation, in ways that are not always clear from the interpretation of remote sensing data and statistics. A simple conceptualization of soybean and cattle production as pure competition, in which each sector has its own dynamics and competes with the other for land, is depicted in Figure 1.1. In SA, the conversion of pastures to cropland is common (e.g., Barona *et al*. 2010). This conversion implies capital transfers from the soybean sector to the cattle sector, which constitute a form of linkage (Figure 1.2). Another form of linkage occurs when a single actor operates in both sectors, as depicted in Figure 1.3.

The conceptualization of soybean farming and cattle ranching as coupled drivers has direct implications on how we view their role in deforestation. Based on the relative intensity of the three forms of land conversion as observed in remote sensing data or statistics, from forest to cropland (F→C), forest to pasture (F→P), and pasture to cropland and back (P↔C), different situations can be inferred, two of which are discussed below.[2]

A situation in which (F→P) > (P→C) may indicate *amplification* (Figure 1.4). We suggest that this may happen when farming indirectly finances deforestation through the ranching sector, and the capital used for the conversion (P→C) is used in part for the conversion (F→P). Because of land price differentials, the capital required for the acquisition of F is less than the capital required for the acquisition of P so that for each hectare that the farming sector acquires from the ranching sector, an amount of capital is transferred to the latter that can be used to acquire more than one hectare of forest. Amplification may occur independently of the profitability of the cattle sector, sometimes within a single company. We propose that this has occurred both under conditions unfavorable to cattle production, such as in 2002–2010 in Argentina (when export-based soybean production was extremely profitable just as cattle prices were falling, and forest to pasture conversion was high and strongly correlated with the soybean economy; see Gasparri *et al*. 2013), and at times when the ranching sector was prospering such as in 2000–2006 in Brazil (Morton *et al*. 2006) and in 1990–1997 in Argentina (Gasparri *et al*. 2013).

When neither farming nor cattle ranching claim large areas of forest, but there is important conversion of land from pastures to cropland, i.e., (P→C) > (F→C) and (F→C), (F→P) are low, the region is undergoing *intensification* (Figure 1). This pattern can be observed in remote sensing data and statistics as an increase in cultivated area with less-than-proportional deforestation, which may be the result of environmental regulations (Macedo *et al*. 2012), economic disincentives (national currency overvaluation and loans restrictions) or technological changes (Gasparri *et al*. 2013). Mechanisms behind intensification have yet to be better documented. For example, when GM seeds and no-tillage agriculture, introduced in 1997 in Argentina, made agricultural production possible on marginal pastures, numerous farms converted from the

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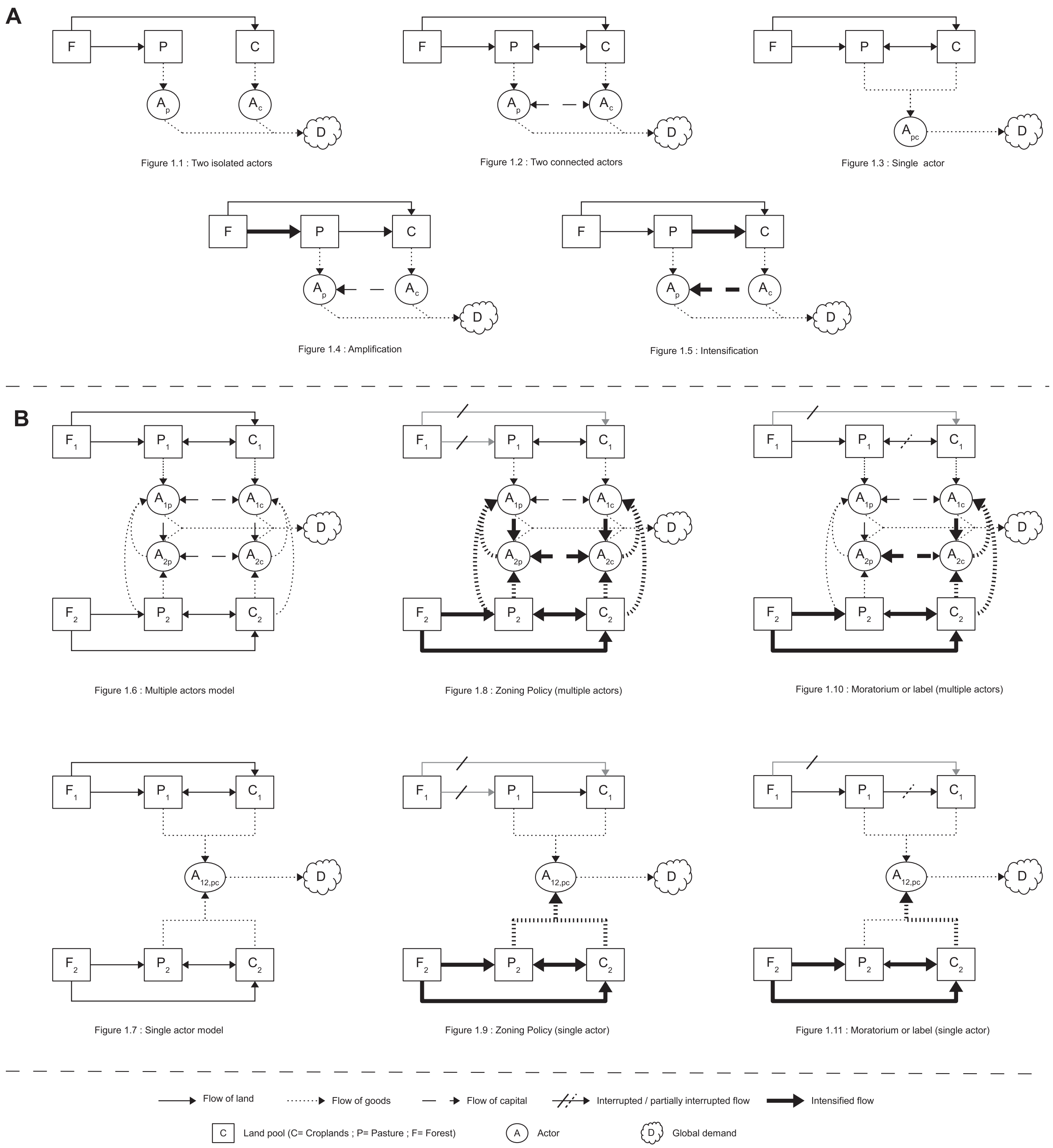

Figure 1 Schematic representation of coupled production frontiers and flows of land, capital, and products under different situations. (A) Soybean and cattle production as a as coupled driver systems in one location. (B) Telecoupling of two production frontiers (two locations) with multiple and single actors and representation of alternative policies for environmental conservation on coupled production frontiers. Lower case letters in panel B indicate location (1 and 2) and productive activities (P: pastures; C: croplands). Note: Flows of goods also imply reverse flows of capital that are not represented for simplicity.

latter to the former (Grau *et al*. 2005). The absence of any large-scale displacement of cattle ranching in the following years might be due to a shift in production of the same actors from cattle ranching to farming, in which capital was mobilized for conversion of pastures to crops rather than for deforestation.

Table 1 Investments of large Argentine and Brazilian soybean-producing companies in the cattle sector and in others South American soybean-producing countries (for a complete listing of companies, see Annex 1)

Large soybean producers from	Investments in other soybean-producing countries in SA (%)	Investments in the cattle sector (%)
Argentina ($n = 17$)	52.9	58.8
Brazil ($n = 13$)	30.8	30.8
TOTAL	**43.3**	**46.7**

These two examples show how the concept of coupled driver systems may be used to enhance our understanding of land use dynamics. Both patterns of land conversion, amplification and intensification, can occur with different but connected actors, or with one integrated actor combining both production activities. Empirical evidence of linkages between soybean and cattle ranching in the form of (P→C) conversion is well documented by statistics and remote sensing data (e.g., Arima *et al*. 2011; Macedo *et al*. 2012). The fact that many of the larger agribusiness companies in Argentina and Brazil are commonly active in both soybeans and cattle (Table 1 and Annex 1), however, suggests that more information is necessary at actor level in order to better understand how the two function as a coupled driver system.

The telecoupling of production frontiers

Here, we expand the framework proposed above to represent two hypothetical locations (Figure 1, panel B), and examine three forms of telecoupling, distinguishable by the type of connections established between these locations. We represent a two-region telecoupled system under two idealized configurations: one with multiple actors connected with each other (Figure 1.6), and one with a single actor (Figure 1.7). For the sake of simplicity, we assume that actors in place 1 are economically dominant, and are the source of investments in place 2. Though the graphs portray the two places as equivalent, in real cases, there are likely to be important asymmetries (e.g., of capital, processing capacity, and technology) influencing the direction of flows between frontiers.

The first form of telecoupling, *telecoupling through demand*, links places 1 and 2 through their supply to a common demand and the associated capital flows. In Liu *et al*.'s (2013) framework, each place can be considered a spillover system of the telecoupled system formed by the other with demand. This differs from a situation in which the two places satisfy separate demands only through distinct channels. In the second form, *telecoupling through trade*, trade between actors links the two places via flows of goods and capital, as soybean producers and cattle ranchers in region 1 (A_{1p} and A_{1c}) source part of their production from soybean producers and cattle ranchers in region 2 (A_{2p} and A_{2c}). This may occur, for example, if A_{1c} sources part of its raw soybeans from A_{2c} and processes them for reexport. In *Telecoupling through land acquisition*, actors in region 1 acquire land in region 2 through purchase or rental. These three situations have been observed in SA, as will be shown below.

During the 1980s and 1990s, the soybean export markets were differentiated among SA countries. Bolivia's production was oriented primarily to the Andean market (Peru, Colombia), Brazil's to Europe, and Argentina's to Asia (except China). In the late 1990s, the Chinese market started to gain prominence in Argentinean exports, while Brazil remained linked with European demand, in part, due to the prohibition of GM seeds until 2005 (Garret *et al*. 2013). Since the 2000s, however, China has clearly been the main market for soybean grain and products from SA (Aide *et al*. 2013), with Europe in second position. The reorientation of separate export markets toward a common buyer can be seen as a process of *telecoupling through demand*.

At the same time as they were reorienting their exports toward China, Brazil and Argentina started to play an intermediate role for soybean exports from Paraguay, which exported a large proportion of its soybeans to Brazil in the 1990s and to Argentina in the 2000s (in the 1980s Paraguay registered direct exportations to UE) (FAO 2014). Bolivia, though it has until recently been exporting mostly to the Andean Nations, is also expected to provide important supplies of soybeans to the Argentine crushing industries in the coming decade. The progressive incorporation of Paraguayan and potentially Bolivian soybean production into the Brazilian and Argentine industry represents an example of *telecoupling through trade*.

Telecoupling through land acquisition is common throughout SA, with the particularity that a considerable part of these land acquisitions happens between countries within the region (Reydon & Fernandez 2013). Countries like Argentina and Brazil are both hosts and sources of transnational investments in land. Of 1 million ha of soybeans in the Santa Cruz department of Bolivia, an estimated 40% was under Brazilian ownership in 2007 (Urioste 2012). Brazilian investments both in Bolivia and

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Table 2 Existing and hypothetical policies in a context of coupled production frontiers

Decision level	Regulation level	Target	Policy example	Description	Potential issues and limitations
Consumer	Company, flow	Forests	Roundtable on Responsible Soy label (RTRS)	The label includes restrictions on the conversion of forests to croplands after a baseline date (or adapted for each country based in land use planning).	Companies may certify only part of their production and are free to invest in deforestation-causing activities locally or in other ecoregions.
Consumer	Company, flow	Amazon forest	Amazon moratorium	Agreement not to purchase soybeans produced in areas deforested in the Amazon biome after June 2006.	Companies are free to invest in deforestation in other ecoregions.
Consumer	Company, flow	Forests	*No-deforestation label	The label would apply to companies selling products originating exclusively in areas not deforested after a baseline date.	The effectiveness would depend on consumer preferences.
Consumer, company	Company	Environment	*Environmental code of conduct	Similarly to the ICMM in the mining sector, a code of conduct would help make companies accountable for the environmental impacts of their activities.	May reinforce asymmetries between producers, with larger companies capturing the better markets; risk of defining low-commitment standards.
Financial institution	Company	Environment	Equator principles	The EP are agreed upon by a number of financial institutions as conditions for loans, and include an environmental dimension.	The impact depends on the adoption of the principles by the main lenders in deforestation areas, and on the definition of an environmental code conduct; companies may source capital from own activities.
State	Territory	Specific ecoregion	Zero-deforestation law in Paraguay's Atlantic forest; Forest law in Argentina	These policies define areas where deforestation is severely limited or prohibited.	Companies may invest in deforestation in other ecoregions.
State	Flow	Forests, natural habitat	*Restrictions on imports/exports of products originating in deforested areas after a baseline date.	Assuming the existence of an origin-tracking system, limits could be set to trading and/or producer companies on the amount of products originating in deforested areas.	If a producer state imposes restrictions, possible leakage to other states; if a consumer state imposes restriction, other buyers may step in and buy without restrictions. The implementation of a tracking system would be costly.

Continued

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Table 2 Continued

Decision level	Regulation level	Target	Policy example	Description	Potential issues and limitations
State	Company, flow	Forest, natural habitat, environment	*Differential taxes according to environmental criteria	Taxes could be lowered for companies that can prove the sustainable origination of their products and raised for others.	Tax differentials would need to be high to provide significant economic incentives, which may be politically difficult.
State, company, consumer	Company, territory	Specific ecosystem or region	*Sustainable production zones	Similarly to foot-and-mouth disease-free areas, regions could be defined that meet sustainability criteria, and products certified to come from these areas.	Companies may invest in deforestation in other places/ecosystems; monitoring would be costly.

Note: Stars (*) refer to policies that have not yet been implemented in the context of agricultural production.

Paraguay increased mostly in the 1990s, whereas in the last few years, investments by Argentine companies have been on the rise (Galeno 2012; Urioste 2012). Today, many agribusiness companies from Argentina and Brazil have activities in Bolivia and Paraguay. Transnational investments in land and production from Brazil to Argentina and vice versa are also common (Table 1 and Annex 1).

Detecting and monitoring the coupling of production frontiers

A process of coupling can be inferred from early signals and from the presence of favorable contextual factors. Favorable contextual factors for the coupling of two production systems may include the existence of economies of scope in the complementarity between both production systems; agronomic practices and research focused on that complementarity; or the existence of geographic areas with suitability for both activities. Early signals of such coupling can be an active land market with sales from one sector to other and/or the existence of actors that shift production form one activity to the other (e.g., cattle to soybean).

For the telecoupling of two frontiers, favorable contextual factors may include institutional aspects such as common infrastructure planning, commercial agreements or technology transfer and cooperation, and asymmetries between regions—one with a strong economy, advanced technology, and a well-developed value chain, and another with a less-developed value chain, cheaper land, and lesser availability of capital and technology. Early signals include increasing relocation of local companies' activities from one frontier to the other, increasing trade in agricultural inputs and products, and increasing knowledge exchange by means of technical and economic missions between the regions.

In either case, data from national statistics and remote sensing provide few clues about the coupling of production frontiers. In order to monitor coupling dynamics, information on flows of products and capital is necessary. Information on product flows (e.g., grain, machinery, or agricultural inputs), commonly available from national and international databases, is valuable for monitoring the telecoupling of frontiers and for separating telecoupling through demand from telecoupling through trade. For the coupling of production systems or telecoupling through land acquisition, information on flows of capitals is necessary. This information is generally considered sensitive by companies and states alike, and is rarely made available to the public, which is a major limitation when studying these processes.

Policy for environmental conservation on coupled production frontiers

The evidence presented above suggests that deforestation processes in different production frontiers of SA are not independent. Nevertheless, conservation policies so far have tended to concentrate on particular locations and production sectors, neglecting their connections.

Territorial governance aims at solving conservation problems in situ, and includes initiatives such as the creation of conservation areas, zoning or local deforestation restrictions. A number of important conservation policies that have been implemented in the 2000s in the countries

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of the Southern Cone were oriented toward developing a conservation area network. At the same time, zoning laws have been passed with the intention of orienting the geographic expansion of croplands. In order to protect its remaining Atlantic Forests, Paraguay introduced a temporary "zero deforestation law" in 2004, still in place today (WWF 2014). In Argentina, the new forest law passed in 2007 created numerous no-deforestation zones (Garcia-Collazo *et al*. 2013).

In parallel to this, a growing number of initiatives have focused on market-based instruments for conservation and may be described as *flow-centered governance* (Sikor *et al*. 2013). The most publicized example in the region has been the soybean deforestation moratorium in the Amazon, a voluntary scheme implemented in 2006 in which companies and federal banks committed to not purchasing soybeans from or providing credit to farmers whose land that was deforested after July 2006. The Roundtable on Responsible Soy (RTRS) also designed voluntary industry standards for sustainability that include the exclusion of areas deforested after a baseline date (RTRS 2014). Similar initiatives exist for others agricultural commodities (e.g., the Roundtable for Sustainable Biofuels).

Representing particular types of existing territorial and flow-centered policies on the framework graphs enables us to see how easily they might induce leakage under a situation of coupling soybean-cattle production frontiers (Figures 1.8 see Annex 2 for a discussion of the assumptions made).

A *zoning policy* that halts deforestation in place 1 will stop flows of land from forest to pasture and to cropland ($F_1 \rightarrow P_1 = 0$ and $F_1 \rightarrow C_1 = 0$; Figures 1.8 and 1.9). It is clear that restricting expansion in place 1, provided that actors have direct or indirect links to place 2, is likely to provoke leakage. This could happen through the transfer of additional capital from demand to actors in place 2 and corresponding expansion into the forest; through the outsourcing of a greater part of the production chain to actors of place 2; or through greater direct involvement of A_{1p} and A_{1c} in production in place 2. In all three cases, greater deforestation leakage is a likely outcome of regulation unless intensification compensates for all the expansion loss in place 1.

A *moratorium* and an *environmental label*, for our purposes, have the same effect, namely, to restrict soy production in place 1. We represent this as a zero flow of land from these forests to croplands ($F_1 \rightarrow C_1 = 0$), and a reduced flow of land from pastures to croplands for complying actor A_{1c} ($P_1 \rightarrow C_1$ is restricted; pastures may still be converted to croplands if they were not deforested after the set date; see Figures 1.10 and 1.11). Given restrictions on expansion in place 1, the complying actor might increase its investments in place 2 through outsourcing (in a multiactor system) or direct use of agricultural land, participating in the chain of deforestation there (provided that forests in place 2 are not affected by the moratorium). Additionally, a label represents a segmentation of the demand. The parts of the demand that are left out of the process may still be satisfied through new forest conversion.

Conclusions and recommendations

This exercise suggests that the coupling of production frontiers creates new channels for capital to promote deforestation, even under some of the more common regulation schemes. Leakage may ultimately occur in virtually any situation through market mechanisms, but we argue that coupling has the potential to considerably accelerate the process. The channels taken by leakage are influenced by the type of policies in place, the configuration of the production chains, and the institutional context. As long as conservation policies on the soybean and cattle production frontiers of SA focus on territories and productive units (fields or plants), they will leave room for the types of leakages described above. From our point of view, these policies and their assessment need to be based on more realistic conceptual models that take into account the increasing coupling between production sectors and geographic locations. The simple assumption of one isolated economic actor associated with one production sector (soybean or cattle ranching) in one location may lead to the design of inefficient conservation policies and increases the risk of achieving local conservation successes that end up having minor overall impacts.

The existence of coordinated and linked economic actors taking decisions over land in multiple production sectors and locations makes it necessary to increase the coordination of land use and conservation policies, particularly in the governments of coupled regions. We argue that actor- and flow-centered policies are a necessary complement to territorial conservation in a context of coupled production frontiers (Table 2 lists some existing and hypothetical policies). In our opinion, short-term adjustments could be made to environmental-label-type initiatives to certificate units of decision making (i.e., companies) rather than production unit (i.e., farms). Aditionally, moving the enviromental controls up the value chain, especially in the more concentrated sectors, might provide greater leverage when operating over flows. Transnationalization and concentration of companies have been common in other sectors such as mining, fishing, or forestry. Policy experiences from these sectors may offer valuable insights for the soybean-cattle system of SA.

In this essay, we highlighted the emergence of coupled prodution frontiers in SA. This coupling process presents the scientific community with the challenge of developing new methodological approaches for the design and monitoring of conservation policies. We made some suggestions regarding the policy and methodological implications of this process, but more work and discussion are necessary in order to test the proposed framework empirically, and to evaluate potential policies in its light.

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1. We use the words displacement for "a geographical shift of land use from one place to another" and leakage for displacement specifically caused by conservation policies (see Meyfroidt *et al.* 2013).
2. In both situations, (P←C) is low or inexistent and is not represented on the graphs.

Supporting Information

Additional Supporting Information may be found in the online version of this article at the publisher's web site:

Annex 1: List of major soybean-producing companies form Argentina and Brazil, indicating countries in which they invest and whether they have investments in cattle production. This list was prepared based on public information available on the companies' websites during year 2013. Number 1 indicates YES and 0, NO.

Annex 2: Assumptions made for the policy analysis.

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