THE **NEW** CLIMATE **ECONOMY**

The Global Commission on the Economy and Climate

Towards Efficient Land Use in Brazil

NEW CLIMATE ECONOMY PROJECT

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Executive Summary

Increasing global demand for food and the need to address climate change risk make it ever more urgent to both protect ecosystems and use land more productively and efficiently. Brazil is a key player in this context and has made significant gains in recent decades. Between 1970 and 2006, its average national cattle farm productivity doubled and its average national crop farm productivity quadrupled. More recently, the country's conservation efforts have been successful in reducing the rate of Amazon forest clearings to its lowest level in 30 years.

This report shows that not only is there significant further potential for simultaneously promoting economic growth and improving ecosystem protection within Brazil's rural landscape but also that substantial improvements are already underway. Well-functioning markets and policies can boost the pace at which these changes are happening and help the country to realize latent land use efficiency gains. Such measures provide an opportunity to embed mitigation of climate change risk and increased food production in an overall strategy for developing the Brazilian rural economy.

This report is organized in three parts.

1. **Misallocation in Brazilian land use: Land abundance shaped institutions and technological decisions, creating inefficient resource allocation**

The intensification of agricultural production is feasible in Brazil without increasing deforestation, and with positive climate mitigation benefits in terms of greenhouse gas (GHG) emission reductions. Considering Brazil's large land area and the extensive portion of this area occupied by pastures, there is substantial physical potential for increasing production and reducing emission by converting degraded pasturelands into crops. For example, Brazil has over 40 million hectares of degraded pastureland outside the Amazon suitable for the production of sugarcane. This represented more than 65% of total Brazilian cropland in 2006. Converting this land to sugarcane production would raise its agricultural value and lower GHG emissions.

Since the colonial period, the use of natural resources in Brazil has been the outcome of a set of policies, institutions and technological choices based on the abundance of land. In the early stages, the country's agriculture saw the emergence of *rentier* landowners and was primarily based on access to slave labor used to farm large tracts of land. More recently, the modernization of agriculture has also been based on a model that is land-intensive. In addition, there are non-agricultural incentives for holding land, mainly associated with tax shelter or protection against macroeconomic risks.

Together these processes have created a massive misallocation problem in Brazilian land use. The large variation in agricultural productivity both within and across Brazilian regions is proof of this. **Within-region differences in productivity imply there is room for boosting economic growth of the rural economy without compromising the protection of natural resources. In other words, growth in agricultural production can be achieved via increases in productivity, at no cost to environmental preservation.**

2. **Learning from the past: Policies, R&D and private investments are levers to change land use at scale**

The second part of the report focuses on three major examples of land use change at scale, showing that the country is already in a process of addressing the inefficiency in land use. **These examples illustrate that (i) it is possible to change land use patterns at scale based on technology innovation and dissemination, private investment and better policies; and (ii) this is a process that reconciles natural protection with economic growth.**

- **Example 1: the Brazilian soybean revolution.** R&D efforts undertaken in the 1970s and 1980s in the soybean sector created business opportunities for the development of the Brazilian Cerrado, increasing income and attracting skilled labour. The adaptation of soy to suit Central Brazil's growing conditions in the early 1970s was a major technological change that reshaped agriculture in the region and integrated it with international markets. The municipalities more suitable to soy production received larger inflows of immigrants with higher educational levels. Moreover, these immigrants were disproportionately drawn from states with more mechanized agriculture and more cooperatives. The combination of technological change and skilled migration increased yields and agricultural output and reduced the demand for land, decreasing the rate in which forests were cleared in Central Brazil.
- **Example 2: the entry of sugarcane mills in the state of Mato Grosso do Sul (MS) in 2000s.** Substantial private investment in the sugarcane business brought large-scale changes as land use moved from low productivity pastures to high productivity crops. Between 2005 and 2012, the number of sugarcane mills in the MS state increased from 8 to 22. Data suggest that GDP in a typical municipality increased substantially after plant construction and there are a number of explanations for this. For example, evidence on the economic effects of yield gains in soybean production suggest that the new sugarcane businesses are likely to have increased farmers' access to capital and boosted investments more broadly. In addition, the industry and the services sectors also benefited from these new investments.
- **Example 3: the adoption of a set of strategic conservation measures, with emphasis on monitoring and law enforcement, to contain deforestation in the Brazilian Amazon.** The Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (Plano de Prevenção e Controle do Desmatamento na Amazônia Legal, PPCDAm), the pivotal conservation policy effort of the mid-2000s, marked the beginning of a novel approach towards combating deforestation in the Brazilian Amazon. Launched in 2004 and implemented at reasonably low cost, it integrated actions across different government institutions and proposed innovative procedures for monitoring, environmental control, and territorial management. The main driving force behind stricter monitoring and law enforcement, the Real-Time Detection of Deforestation (Detecção de Desmatamento em Tempo Real, DETER) system captures and processes georeferenced imagery on Amazon forest cover in 15-day intervals. These images are used to identify deforestation hot spots and target law enforcement efforts. As a result, the deforestation rate decreased from 2.7 million hectares in 2004 to about 460 thousand hectares in 2012.

3. **Looking ahead: Possible pathways to improving economic and environmental returns from land use**

Agricultural production in Brazil is undertaken in a relatively small portion of its national territory. Agricultural lands account for roughly 26% of Brazil's total surface area, divided between (low productive) pastures (75%) and croplands (25%). Levels of productivity vary substantially, particularly among cattle ranchers and small farmers. This is the case even within areas with very similar geographical characteristics. Such variation points to a pervasive and substantial misallocation problem. In-depth knowledge about rural technology adoption behavior and market failures affecting agricultural production is therefore essential to steer agricultural policy towards setting effective incentives for high-productivity agricultural production.

CHALLENGES AND OPPORTUNITIES IN AGRICULTURE

To help the design of policy actions that can improve land use, this report identifies and enhances understanding of the mechanisms driving the key socioeconomic issues that affect agricultural production in the country. Evidence suggests that improving agricultural productivity depends on a number of factors, namely improving technology dissemination, well-functioning financial instruments and land rental markets, and better quality infrastructure.

Disseminating information on new practices and their associated technologies is key

Innovation is a main driver of productivity gains and land use changes. The Brazilian soybean revolution is a key example on that front. Another example is the development of the biofuels and the ethanol industry. In both cases, there were substantial changes in farming and land use.

However, the realization of these gains depends upon the process through which the technology and new practices are disseminated to farmers. Barriers to their adoption can have serious consequences for the efficient use of natural resources. These barriers should be considered in the policy design. An interesting example for Brazil is the spread of a no-till farming method called the Direct Planting System (DPS) where learning from peers, especially from those whose land shares similar characteristics, has been shown to catalyze technological adoption. Environmental characteristics, such as soil dissimilarity, affect the adoption of a new technology. These findings suggest that, in order to increase agricultural productivity, it is not sufficient to invest in innovation, develop business models, and marginally subsidize adoption. Achieving technology diffusion requires the dissemination of information on new techniques and their associated technologies. Agricultural extension efforts that aim to educate farmers on new practices should complement innovation efforts.

More efficient land markets for sales or rentals can attract skilled operators to otherwise unused or unproductive land

Deregulation of land rental markets, more secure land rights, and more effective means of resolving legal conflicts around land could contribute to more effective land use.

Given the country's long history of macroeconomic instability, land ownership in Brazil yields non-agricultural benefits, such as hedging against inflation. In this context, an active land rental market offers means to improve land use efficiently by placing more skilled operators on otherwise unused or unproductive available land. However, when compared with other countries, Brazil's land rental markets fall short.

The insecurity of property rights and the lack of effective dispute resolution mechanisms are both parts of the problem, particularly in a Latin American context. An additional explanation is the imperfection of the legal system. Restrictions on rental contracts, imposed by land and labor legislation, excessive guarantees provided to renters, and the insecurity generated by land reform have created disincentives to the growth of rental markets.

Well-designed public provision of credit and agricultural risk management can increase investment and reduce deforestation

The economic literature provides empirical evidence that the availability of credit and insurance leads to significantly larger agricultural investment and innovation in agriculture. About 20% of the regional variation in Brazilian agricultural productivity is associated with credit availability, suggesting that greater access to credit could improve productivity. On the other hand, policies that increase the availability of financial resources should be aware of potentially adverse rebound effects. For instance, there is evidence that the reduction in the availability of credit caused by Resolution 3,545, which conditioned the concession of rural credit upon proof of compliance with legal and environmental regulations, helped contain deforestation in the Amazon biome. This suggests that policies that increase the availability of financial resources may lead to higher deforestation rates. Instruments will need to be designed carefully to achieve economic and environmental goals.

In addition, the current instruments available for price risk management are inefficient. Instead of having the government buying farmers' output as a way of guaranteeing a minimum price, the development of market-based instruments could improve farmers' ability to deal with risk.

Improved infrastructure can increase agricultural productivity if the incentives are right

Providing infrastructure is key to enhancing the competitiveness of economies and increasing agricultural productivity. Despite being one of the most prominent agricultural producers in the world and an important exporter of agricultural commodities, Brazil suffers from poor transport infrastructure. The World Economic Forum (WEF) ranks it at 77th out of 148 countries (WEF, 2014), lagging behind other emerging and developed economies in roads, railways and port infrastructure. A lack of road infrastructure keeps production from being exported through more cost-effective ports – in some cases increasing costs by almost twenty times, with an adverse impact on productivity.

However, Brazil faces important challenges in the design of the regulatory framework. Since the late 1990s, the regulatory environment of Brazil's infrastructure has been in continuous flux, creating uncertainty in the marketplace. While the regulations have changed in different ways, the general trend of these changes has been to prevent existing infrastructure concessionaires from making long-term profits from their investments, with regulation becoming more complex as the regulator gradually takes the role of the market as a provider of incentives. These actions have often led to taxpayer-funded subsidies to motivate the concessionaires in place of marketplace incentives, to inefficient use of the infrastructure, and to the promotion of inefficient firms. This shifting mix of incentives has diminished the viability of infrastructure investments and led to the erosion of the infrastructure's overall quality. Addressing inefficiencies in infrastructure regulation could yield large gains in infrastructure improvements and agriculture productivity.

CHALLENGES AND OPPORTUNITIES IN FOREST PROTECTION

Meeting increasing global demand for agricultural commodities will create huge opportunities for business. However, agricultural expansion is a major driver of land use change, and forest degradation and deforestation are particular concerns. Brazil has a vast territory (852 million hectares), most of which is still covered by native vegetation. Through the past decade, Brazilian conservation policy efforts focused mostly on combating deforestation in the Amazon biome. Amazon forest clearings have slowed significantly in recent years thanks to these policies, combined to declining agricultural output prices.

The main driving force behind stricter monitoring and law enforcement, the Real-Time Detection of Deforestation (Detecção de Desmatamento em Tempo Real, DETER) system captures and processes georeferenced imagery on Amazon forest cover in 15-day intervals. These images are used to identify deforestation hot spots and target law enforcement efforts. Prior to the activation of the satellite-based system, Amazon monitoring depended on voluntary reports of threatened areas, making it very difficult for law enforcers to identify and access deforestation hot spots in a timely manner. Further progress will require additional policy adjustments.

Shifts in Amazon deforestation to smaller clearings require adapted policies

Recent changes in patterns of deforestation present new challenges for further reducing Amazon forest clearings. In the early 2000, Amazon deforestation was mainly due to the clearing of large contiguous areas of forest. In recent years, however, deforestation has been driven mostly by the cutting down of forest in small increments, possibly to elude Brazil's Amazon monitoring capacity, since deforestation of areas smaller than 25 hectares are not detected by DETER satellite imagery (Assunção J. , Gandour, Hemsley, Rocha, & Szerman, 2013). An increased focus on small deforestation will be critical. Given differences in how regions and individuals have responded to past policy, it will be important to tailor policies to address regional differences and landholder behavior in clearing patterns.

Combating deforestation beyond the Amazon remains a challenge

The creation of protected areas is another important conservation policy as the Ministry of the Environment's uses this designation to prevent deforestation, particularly in the central region of the Amazon biome. This and other conservation policies mean that currently, there is typically very limited deforestation occurring inside Amazon protected areas. However, increasingly substantial deforestation takes place in their immediate surroundings. Indeed, clearings within protected territories account for less than 10% of total annual Amazon deforestation. In contrast, from 2002 through 2011, the share of total annual Amazon deforestation occurring within 10 kilometers of protected areas rose from 15% to 24% (Assunção J., Gandour, Hemsley, Rocha, & Szerman, 2013). Combating deforestation in Brazil's ecosystems beyond the Amazon remains an important challenge. In order to achieve this, Brazil needs to extend effective monitoring and law enforcement policies over its five major biomes: Cerrado (savannah), Caatinga (xeric shrubland and thorn forest), Atlantic Forest, Pantanal (wetlands) and Campos Sulinos (grasslands), which are also very rich in biodiversity and carbon stocks, and provide a number of ecosystem goods and services. This is particularly important for the Cerrado biome, where native vegetation has been cleared to make way for increasing agricultural development.

Improving enforcement of environmental regulation within private landholdings is essential

The protection of natural vegetation falls under different legal regimes according to whether land is in the public or private domains. On public lands the main instrument for the protection of vegetation is the establishment of a network of protected areas. On the private lands, Brazilian legislation imposes some land use limitations in order to preserve native vegetation. Improving enforcement of environmental regulation within private rural landholdings is essential since forests occupy about a third of the area of rural private land in Brazil, totaling 100 million hectares of native vegetation within private properties.

The Brazilian Forest Code establishes the regulatory framework for environmental conservation in private lands. It requires that a percentage of the area in a property be left in forest or its native vegetation as a Legal Forest Reserve. It also imposes that the native vegetation in sensitive areas such as on steep slopes and along the margins of rivers and streams be conserved as Areas of Permanent Protection.

Although the first Brazilian Forest Code dates from 1934 and a more modern version was enacted in 1965, the lack of law enforcement has led many landholders to fully exploit all of their land. However, in the last two decades, the Brazilian government has improved the enforcement of the law, leading to an intense reaction from the agro-industrial sector, which intensified the pressure to weaken the requirements of the Forest Code.

After over a decade of debate and concessions by both parties, the Brazilian Congress finally approved the Federal Law nº 12,651, on July 25, 2012. Although the new Forest Code retained the same structure and basic concepts as the old one, it established new rules, parameters and penalties, and provided amnesty for landholders who had illegally cleared forest prior to 2008. In addition, it established the Rural Environmental Registry (CAR), the key instrument for enforcing this framework.

Although both framework and instrument are in place, effectively implementing the Forest Code remains a challenge. In particular, uncertainties regarding the enforcement of the Forest Code compromise land owners' efforts, increasing their perception of risk and insecurity.

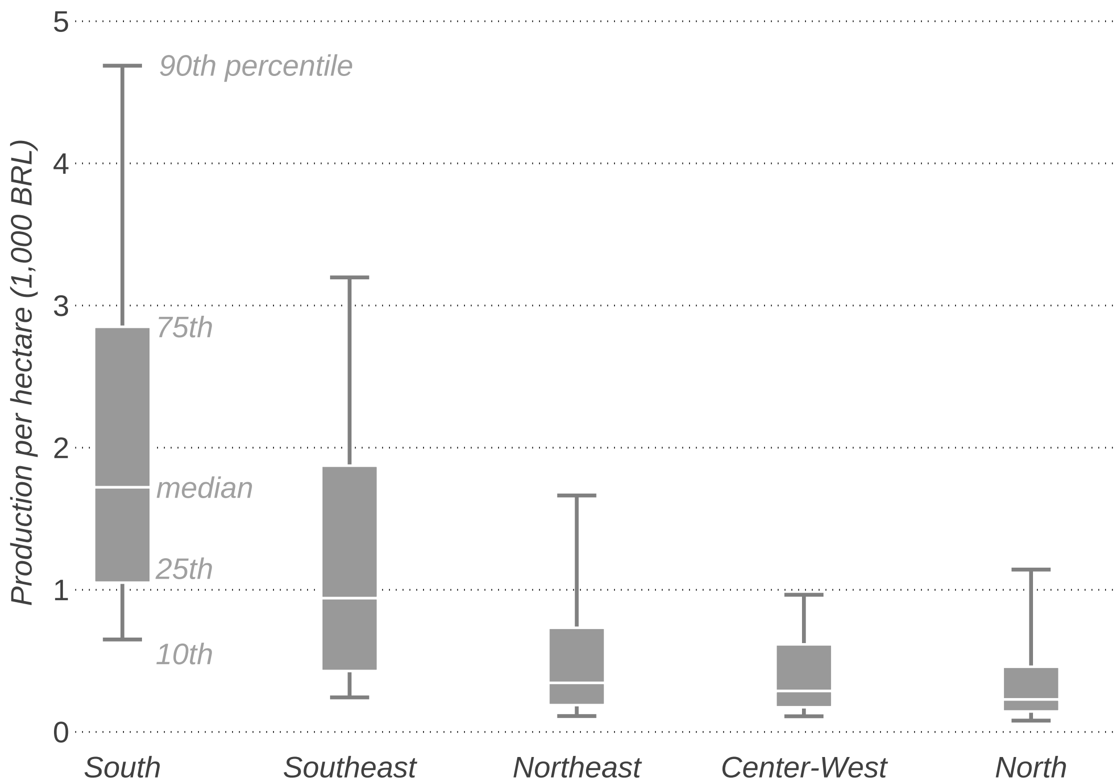
1. Misallocation in Brazilian land use

A substantial part of the Brazilian territory is covered by native vegetation, while agricultural production occupies a relatively small part of the territory. In 2006, the last year when comprehensive data is available, only 26% of the territory was used for agriculture, divided between crops (1/4) and (predominantly low productive) cattle raising (3/4).[1] This section addresses the question of whether there is potential to increase agricultural production at scale without compromising native vegetation by examining evidence of misallocation of natural resources in Brazil (Section I.1) and describing its historical determinants (Section I.2), both in the early stages and following the modernization of Brazilian agriculture.

BRAZIL FACES MASSIVE MISALLOCATION ISSUES

The scope for improving agricultural production while protecting natural resources is determined by the efficiency of current land use. A proximate way of evaluating the efficiency in land use is to assess variation in agricultural productivity. Figure 1 shows that there is large variation in agricultural productivity, both across-regions and within regions. Variation in agricultural productivity that is not associated with geographical characteristics implies that it is possible to increase production without compromising protection of natural resources. **In Brazil, only one third of the variation in agricultural productivity across municipalities is due to geographical characteristics – access to technical assistance, use of specific agricultural practices, infrastructure and credit contribute substantially to further explain this variation.**[2] In other words, evidence suggests that it is possible to increase agricultural production by overcoming barriers that prevent farmers from better allocating their resources.

Figure 1 - Variation in agricultural productivity (2006)



Note: The figure shows the variation in productivity measured as the value of agricultural output per hectare at the municipality level, by region. The upper whiskers show the 90th percentiles of municipalities' productivity; the upper box edges show the 75th percentiles; the white marks show the medians; the lower box edges show the 25th percentiles; and the lower whiskers show the 10th percentiles. Source: (Assunção J. , Gandour, Hemsley, Rocha, & Szerman, 2013).

1 Assunção, Gandour, Hemsley, Rocha, & Szerman (2013)
2 Assunção, Gandour, Hemsley, Rocha, & Szerman (2013)

Agricultural productivity also varies across and within the multiple land uses. It is possible to increase agricultural production by improving yields in cattle raising and in each one of the crops. But there are other potential gains of converting lands across sectors, especially from pastures to cropland. According to the 2006 Agricultural Census, cattle raising is the most land-intensive activity in Brazil, taking place on 160 million hectares and accounting for about 20% of agricultural production. Crops, on the other hand, are cultivated in nearly 60 million hectares and represent 77% of the agricultural production.

The current misallocation in Brazilian land use is the outcome of a long process in which land abundance shaped policies, institutional and technological choices since the colonial period.[3] A brief description of the main elements of this process can shed light on some of the key challenges and opportunities faced by Brazil at this moment.

HISTORICAL DETERMINANTS OF LAND MISALLOCATION[4]

EARLY STAGES OF BRAZILIAN AGRICULTURE

The agrarian structure of the colonial period was determined by the combination of slavery and *sesmarias* – large tracts of granted lands with property rights conditioned upon production. According to Reis (2014), 'the rise of Brazilian slavery in the XV century can be explained as the institutional solution which made feasible the emergence of a *rentier* landowner class within a context of land abundance. Rent was derived from the ownership of labour, the scarce factor, not from land property itself."

A salient example of this process is the first sugar cane boom. In the early stages of colonization, Portugal established a plantation system operated by large farmers (*senhores de engenho*) with slave labor. Economies of scale in sugar mills and land availability induced Portugal to assign lands (and local power) to individuals with enough funds to invest in the purchase of large numbers of African slaves. This agrarian structure has also helped to ensure a constant flow of rents to Portugal. The first sugar cane boom took place mainly along the Northeastern coast, until the XVIII century. Municipalities that were more exposed to the boom display higher land concentration still today.[5] Similar processes determined the modes of production of most of the Northeast and Center-South regions. The availability of slaves fostered the expansion of a slash-and-burn agriculture, with extensive farming practices, without incentives for yield gains or increasing labor productivity.[6]

Cattle raising was, since the beginning, an important component of the territorial occupation process, following the expansion of the main economic activities. Besides food, cattle provided means to overcome the lack of transport infrastructure or even help entitlement in cases in which property rights were based upon effective use of land. Late in the XVI century, cattle raising followed the sugar cane boom in the Northeast. The Jesuit Missions introduced cattle raising in the South early in the XVII century. Then the cattle followed the gold boom in Minas Gerais state in the XVIII century. It was brought to Rio de Janeiro with the arrival of the imperial family. More recently, the cattle raising activity expanded towards Northwest and reached the Amazon biome in the 1970's.[7]

THE MODERNIZATION OF BRAZILIAN AGRICULTURE

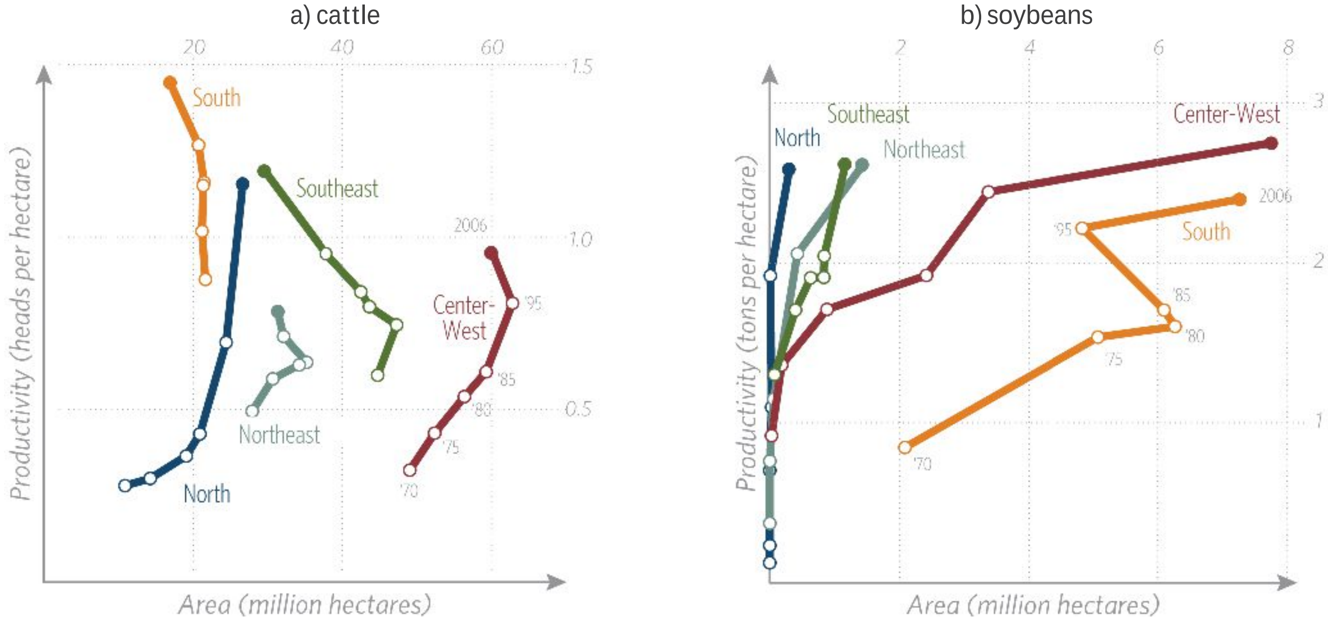
Important changes have taken place in the patterns of land use in the post-war period in Brazil. The share of crop in farm area went from 9.5% to 22% of cultivated/pasture area from 1940 to 2006. Particularly after the nineties, crop areas decreased in the South and Northeast regions, while they increased strongly in the North-West due to the incorporation of new frontier lands.

The growth of pasture areas was noticeably slower, with the share of pasture areas oscillating from 45% in 1940 to 52% in 1970 and 49% in 2006.

Figure 2 gives more details on the evolution of two important sectors in Brazil from 1970 to 2006, namely cattle ranching and soybean. The Southeast region has seen a strong conversion of pastureland to cropland, especially sugarcane, since 1975. A similar trend has started to occur in Brazil's Center-West in 1996, as soybean cropland moved into areas once occupied by pasture.

3 Reis (2014)
4 This section is primarily based on Reis (2014)
5 Naritomi, Soares, & Assunção (2012)
6 Reis (2014)
7 Reis (2014)

Figure 2 – Evolution of Productivity and Area for Cattle and Soybean, 1970-2006



Source: (Assunção J. , Gandour, Hemsley, Rocha, & Szerman, 2013)

Furthermore, a few patterns emerge from panel (a). First, most of the pasture area in the country has been in the Center-West. Second, productivity grew steadily throughout this period in all regions. Third, the Northeast is the least dynamic region in both dimensions depicted in the graph. On the other hand, panel (b) shows that land used for soybean production has expanded across all regions, while productivity levels have converged. Until 1975, only the South had significant soybean production. The Center-West began producing in 1980,with productivity levels slightly higher than those of the South. Production grew in both regions until 1996; by 2006, the Center-West displayed both better productivity and a larger cultivated area than the South, which experienced a 4-fold expansion in cultivated area.[8]

Changes in land use patterns are associated with broader changes taking place in the Brazilian economy. In the post-war period, Brazil suffered drastic demographic and economic changes related to industrialization, urbanization, internal migration, and demographic transition. The rural population decreased from 55% in 1940 to 16% in 2006, while the share of agriculture in Brazilian GDP went down from 37% to 5.5%.

Employment numbers indicate strong growth until 1975, stability until 1985 and a sharp decline afterwards. The average employment figures per farm show steady declines from 5 to 4 in 1950-75 and 4 to 3 in 1985-2006. These trends can be largely explained by the mechanization of the Cerrado since 1985.

These changes reflected heavily in the organization of the national agrarian structure. Between 1940 and 2006, the number of farms increased from 1.9 to 5.2 million, while the farm area went from 198 to 355 million ha, corresponding, respectively, to 26% and 42% of the geographic area of the country. Thus, the average farm size declined from 104 to 68 ha. This movement happened with strong intensity in the fifties and sixties, and has leveled afterwards, and could be explained by investments in transport, which pushed the agricultural frontier, and mechanization.

There is, however, stability in the degree of land ownership concentration. The share of farms larger than 1,000 ha represented 1.5% of the number and 48% of the area, in 1940, and came to 0.75% and 40%, in 1970, and 1.2% and 42.3%, in 2006. During the same periods, the number of farms smaller than 10 ha went from 34% to 51.7% and 47%, and their area went from less than 1% to 2.24%, and 2.23%. Gini coefficients have been identical in all the three Agro Census of 1985, 1995 and 2006: 0.86.

A number of factors contributed to the above mentioned changes. The modernization of Brazilian agriculture relied on the participation of the government through public investment in transportation and agricultural research, and fiscal and credit incentives.

8 (Assunção J. , Gandour, Hemsley, Rocha, & Szerman, 2013)

Infrastructure: Brazil experienced a strong process of road expansion in the sixties and seventies, but it almost came to a halt with the fiscal crisis of the eighties, and experienced a slow recovery in the nineties. However, in the agricultural frontier zones, notably in the North and Center-West regions, road expansion has been strong, mostly financed by the State or local sources. This effectively means that vast new areas of the country are now opened up for agricultural production.

Research: Agricultural research has relied mainly on the Brazilian Agricultural Research Corporation (EMBRAPA), a state-run agency founded in 1973, that operates in close cooperation with local and private producers and rural enterprises. EMBRAPA research produced significant breakthroughs in biochemical technologies, soil management techniques, and cultivar adaptations to the agricultural and climate conditions prevalent in Brazil. EMBRAPA played an important role in the diversification of crops, mechanization, dissemination of chemical inputs, and the shift of the agricultural frontier towards the North-western regions of the country. Its most successful cases include the adaptation of soybean and cotton varieties to the Cerrado regions, and the significant increase of efficiency levels in cattle raising activities. EMBRAPA's innovations focused on land using and labor saving technologies, particularly in the Cerrado, a region especially suited to mechanization.

Credit and financial incentives: Credit incentives played a strong role in stimulating agricultural production and efficiency, and fostering technological innovation. From 1964, with the creation of the National System of Rural Credit, land owners could obtain government subsidized loans at special rates that were well below those offered by the markets. In the 70s, with hyper-inflation, the system became even more attractive, as subsidized credit lines reached negative real interest rates. By the 80s, indexation of interest rates was introduced, which made these loans less desirable, effectively reducing the subsidies and the volumes of credit throughout the agricultural sector.

However, as credit became scarcer and more selective, only large landowners were able to tap into these resources, by providing their lands as collateral. These were mainly farmers that produced crops for the export market and were substituting their own capital, invested elsewhere, for subsidized funds. What followed was a wave of agricultural investments that stimulated production efficiency and fostered technological innovation, but was mostly concentrated in these very large farms. This, in turn, led to a further concentration of rural wealth and properties as the smaller producers were driven away from the market.

The best option for the small, lower efficiency farmers was to sell their land to the larger farmers and buy cheaper plots in agricultural frontier regions, thus extending the amount of rural land in the country. These frontier lands needed strong technological support in order to be efficient and so, as the agricultural frontier expanded towards the North and the Center-West, the use of technological innovation by the frontier producers increased strongly. Therefore, subsidized credit and higher land prices played an important role in the introduction of mechanization and chemical inputs, as well as in the expansion of the agricultural frontier in the Center-Western and Northern regions of the country.

This process was reinforced by the fact that Brazilian agriculture has always been a tax shelter. The country has a long history of macroeconomic instability and land is an important economic asset that has additional values other than those derived from its use in agriculture and collateral, including as a mechanism of protection against aggregate uncertainty. Land prices would increase because of its position as an asset protected from taxation, especially in periods of hyper-inflation, when landownership provided very good protection against inflation tax.

2. Key lessons from the past

Addressing the historical misallocation of land use presents an opportunity to develop the economy while protecting natural resources. This section presents three examples in which innovation, private sector investment and public policies have improved land use at scale in Brazil by combining economic growth with environmental protection:

- Section II.1 reviews how R&D efforts, undertaken in the 1970s and 1980s in the soybean sector, contributed to land use changes and to the development of the Brazilian Cerrado, creating business opportunities, increasing income, attracting skilled labor, and increasing agricultural productivity and output.
- Section II.2 shows how private investment in the sugarcane industry in Mato Grosso do Sul (MS) in the 2000s contributed to major land use change, from low productive pastures to high productive crops, generating population inflows, and positive spillovers not only in agriculture but also in other sectors.
- Section II.3 shows how governmental policy improving law enforcement and monitoring was effective in containing deforestation in the Brazilian Amazon, at reasonable cost, with no adverse impact on agriculture. The empirical evidence provided by these examples support the idea that the protection of natural capital is compatible with economic growth.

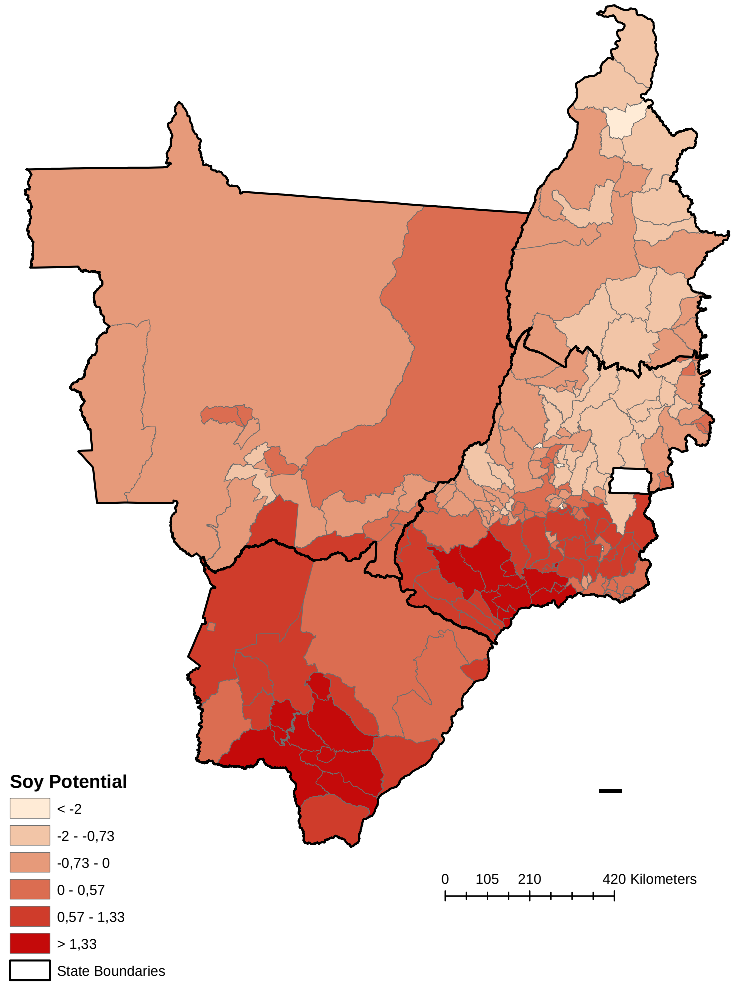
THE IMPACT OF INNOVATION IN THE BRAZILIAN SOYBEAN REVOLUTION[9]

The expansion of soybean in the Brazilian Cerrado allows us to investigate to what extent innovation in agriculture drove land use changes at a time when policies were not addressing environmental issues explicitly. To analyze this issue, it is important to isolate the impact of innovation from other determinants of land use change present in that period, like the process of land occupation, changes in demand for agricultural products, and so on.

The empirical strategy adopted by (Bragança & Assunçao, 2014) to assess the impact of innovation on land use is based on the idea that the adaptation of soybean to growing conditions in the Brazilian Cerrado was a process that affected municipalities differently. This strategy is similar to that adopted in Bustos, Caprettini and Ponticelli (2014), in which the physical production potential is used as a proxy for innovation. Figure 3 maps soybean potential across Central Brazil. Darker municipalities have higher soybean potential while lighter municipalities have lower soybean potential using modern technologies. In the absence of soybean adaptation, changes in agricultural outcomes would have been the same in municipalities with higher and lower soybean potential and similar characteristics.

Results were obtained from the econometric analysis of 193 municipalities in the four states of Central Brazil, i.e., Goiás, Mato Grosso, Mato Grosso do Sul and Tocantins based on the concept of minimum comparable areas from the Institute for Applied Economic Research (IPEA), which makes spatial units comparable through time. Data came from Agricultural Census from the years 1960, 1970, 1975, 1980 and 1985.

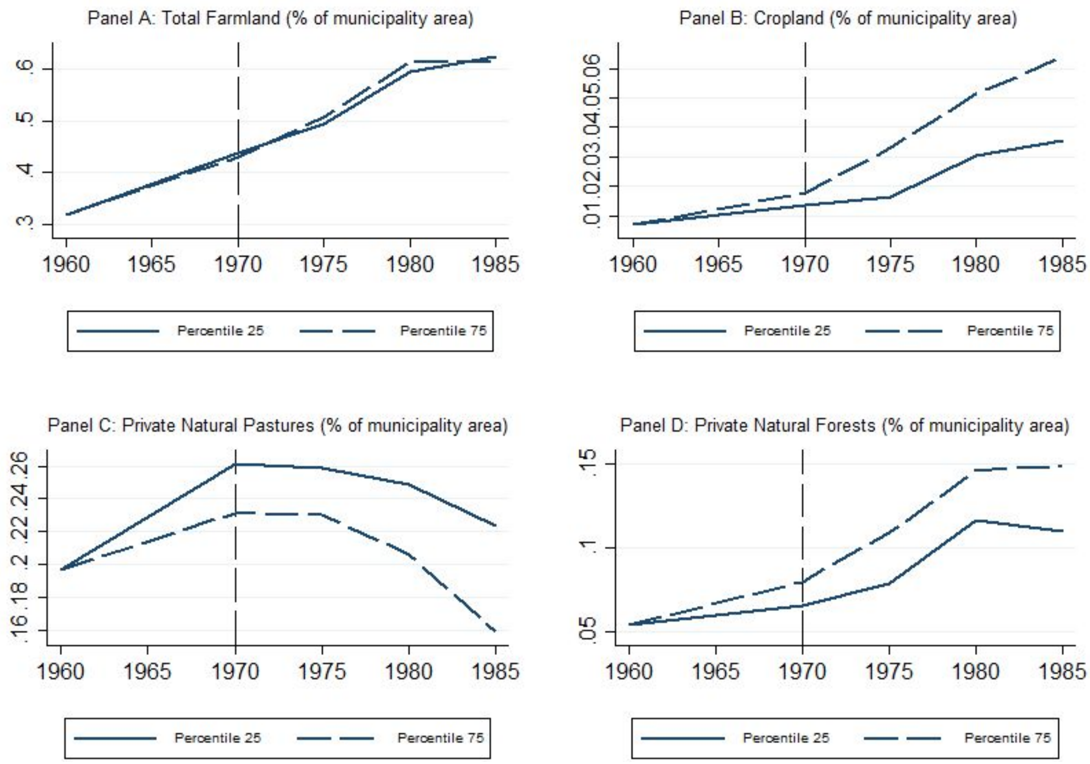
Figure 3: Soybean Potential across Central Brazil



Note: Data are from the GAEZ database. The map presents the value of the soybean potential measure for each of the sample 193 municipalities. The map was constructed combining the contemporaneous municipalities' maps with information from the Minimum Comparable areas from the Brazilian Institute of Economic Research (IPEA). Source: (Bragança & Assunçao, 2014). Source: (Bragança & Assunçao, 2014)

9 This section is primarily based on (Bragança & Assunçao, 2014)

Figure 4: Simulated Changes in Land Use in 75th versus 25th percentile of Soybean Potential



Note: The figure simulates the change in land use in a municipality in the 75th percentile of the soybean potential distribution compared to a municipality in the 25th percentile of this distribution. The outcome variables are indicated in the panel title. To simulate the change in land use, all variables apart from the soybean potential are evaluated at their mean. Soybean potential is evaluated in the 25th percentile of the soybean potential distribution in the solid lines and in 75th percentile of the soybean potential distribution in the dashed lines. Source: (Bragança & Assunçao, 2014). Source: (Bragança & Assunçao, 2014)

The analysis estimates how different the dynamics of land use change were in the municipalities more affected by technical changes in soybean production than in those less affected.

Figure 4 shows that, although there was no difference in the expansion of farmland, land use inside farms changes dramatically across municipalities with more and less innovation. The agriculture frontier moved equally in both cases. However, those municipalities more affected by the technical change increased cropland and reduced pastures, with a net positive impact on natural forests inside private properties. These changes indicate that technological innovations induced farmers to expand agriculture in the intensive margin and invest in agricultural intensification, reducing total land use. They also indicate that technical change generated environmental benefits, decreasing the rate in which forests were cleared in Central Brazil.

This evidence suggests that, even without a clear concern with environmental issues, innovation in the agricultural sector is not associated with land expansion in a place facing the misallocation problems described in the previous section. The expansion observed in the Cerrado in that period is associated with other factors that also impacted the less affected municipalities. **The isolated impact of innovation was beneficial with respect to economic growth and forest protection.**

SUGARCANE MILLS DRIVE PRODUCTIVITY GROWTH IN MATO GROSSO DO SUL[10]

Between 2005 and 2012, substantial private investment in the Brazilian state of Mato Grosso do Sul (MS) resulted in the construction of 14 sugarcane mills and an increase in the sugarcane area of more than 300%, compared to an increase of almost 70% in Brazil over the same period. MS is similar in area to Germany and so this episode shows how feasible it is to change land use at scale –. Land for sugarcane production was mainly found by converting pastureland, and, in a smaller degree, land for annual crops. The sugarcane expansion also created positive co-benefits for agriculture, particularly by increasing grain productivity, and for other economic sectors.

Set up as a response to the 1973 oil crisis, Brazil's National Alcohol Program (Proalcool) represents the largest program of

10 This section is primarily based on (Assunção & Pietracci, What Happens When Sugarcane Comes to Town? Evidence from Brazil, 2014)

commercial biomass utilization in the world. Thanks to this program and the introduction of vehicles that could run on pure ethanol, the Brazilian biofuels industry grew rapidly until the late 1980s, when falling oil prices, rising sugar prices and a cutback of subsidies led to a decline in ethanol production.

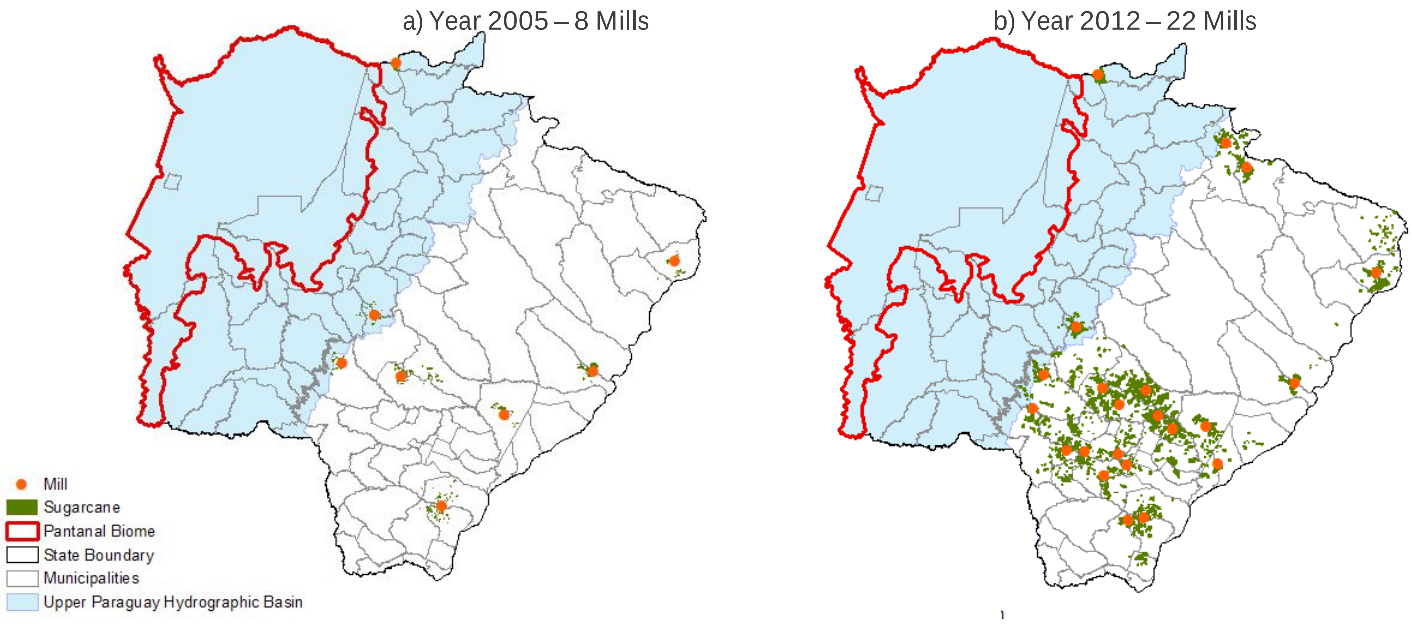
However, in 2003, a technological breakthrough reached the market, offering Flexible Fuel Vehicles (FFVs), with engines that could run on any blend of hydrated ethanol and gasoline. This technology was a quick success, and by 2005 domestic sales of FFVs surpassed that of gasoline-only fueled vehicles. By 2012, this number had reached 87%. This innovation quickly led to an increase in the demand for ethanol and, thus, sugarcane, triggering a supply side investment boom in new sugarcane plantations and greenfield mills. Furthermore, mandatory blending of anhydrous ethanol into gasoline was originally introduced by Proalcool. The minimum required blending percentage has varied over time, and currently ranges from 18% to 25%.

Traditionally, the Brazilian sugarcane and ethanol industry is concentrated in the Center-South region, especially in the state of São Paulo, which saw its sugarcane crop area increase from 12.4% to 20.7% from 2005 to 2012. However, as land for crop expansions grew scarcer, producers started to look at neighboring states, such as Paraná, Mato Grosso do Sul (MS), Minas Gerais and Goiás.

The highest rate of sugarcane harvested area in the referred period occurred in MS, where investors were attracted by fiscal incentives, low priced land, adequate soil and climate conditions, existing infrastructure and proximity to the domestic ethanol and sugar markets and to the port of Santos, the main exporting route.[11] The state had eight ethanol and sugar mills in operation in 2005, but by 2012 there were 22, an almost threefold increase, while sugarcane area increased fourfold from 136,803 to 558,664 hectares.

This potential was identified in 2008 by a study from the Ministry of Agriculture, Livestock and Food Supply (MAPA) and Ministry of the Environment (MMA)[12] that showed that the state had about 10,8 million hectares of land currently under pasture or agriculture with high, medium and low suitability for sugarcane crops, a figure which is slightly more than the area of Portugal. This study was the basis for a Federal Decree (n. 6.961 from 2009) that identified potential areas for sustainable sugarcane production. The referred Decree created a sugarcane agroecological zoning (ZAE Cana), forbidding new sugarcane plantations and greenfield mills in the Pantanal biome and Upper Paraguay hydrographical basin. It must be noted, however, that this particular legislations does not forbid other agricultural activities in these same areas. Assunção & Pietracci (2014) study the impact of the construction of new sugarcane mills using yearly data from 78 municipalities in MS, for the 2005-2012 period (Figure 5).

Figure 5: Mills and Sugarcane Crops (Before and After)

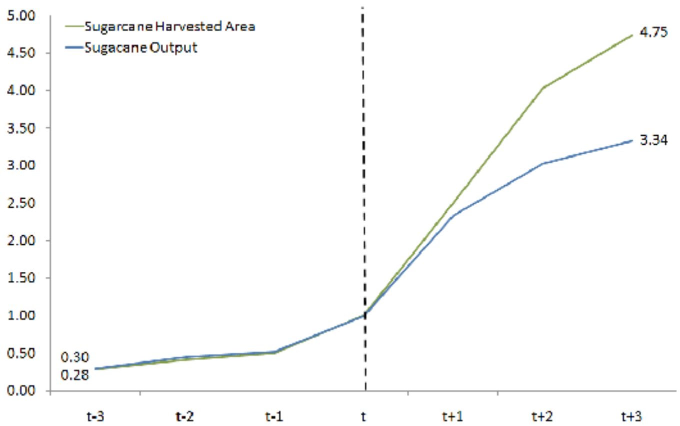


Note: Mills' locations and entry timeline from BioSul - Associação dos Produtores de Bioenergia de Mato Grosso do Sul. Sugarcane satellite images from CANASat, from INPE - National Institute for Space Research. Source: (Rudorff et al., 2010; Adami et al., 2012; Assunção & Pietracci, 2014)

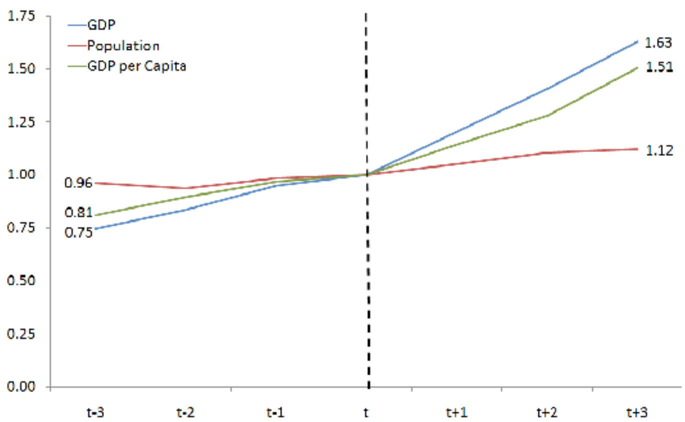
11 (Pereira, Michels, Rodriguez, Campelo, & Muerer, 2007)
12 (EMBRAPA, 2008)

Figure 6: Behavior of Selected Dependent Variables for a Representative Hosting Municipality

a) Sugarcane harvested area and output



b) GDP, population, and GDP per capita



Note: Main dependent variables were normalized at one at the time of mill's entry and the average was calculated to elicit dynamic behavior for a representative hosting municipality. Source: (Assunção & Pietracci, 2014)

The construction of a sugarcane mill changes dramatically the history of small municipalities like those in MS where projects were deployed, with capital expenditures accounting for approximately 75% of GDP in hosting municipalities. The paper explores dynamics of many variables of municipalities with new sugarcane mills with those from the other municipalities where a new mill is absent.

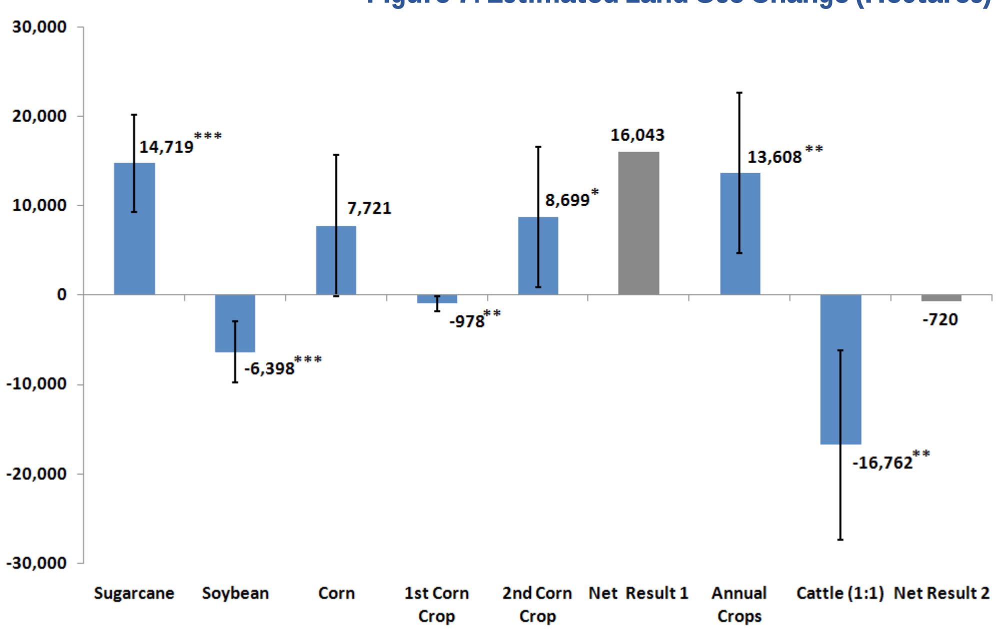
Figure 6 shows sugarcane harvested area and output increasing prior to the beginning of the mill's operation, followed by increases in GDP, population and GDP per capita. Three years after the beginning of the mill's operation, the area of sugarcane harvested increases by 375% while sugarcane output increases by 234%. GDP also undergoes a structural change with different growth rates for agriculture, industry and services.

It is possible to identify major land use changes caused by the entry of a mill. Data from the National Food Supply Company (CONAB) shows that, in MS, 318,128 hectares were converted into sugarcane crops since the 2007/2008 harvesting season, mostly pastureland (88%) and annual crops, soybean and corn (11%). Estimated net land use change, however, remains almost zero (Figure 7).

Mello et al. (2014) estimate that the carbon payback time from converting pastureland into sugarcane to produce ethanol would be between 5 to 6 years. If pastureland is degraded or if the conversion is from annual crops, there would be a carbon credit from the conversion.

If native Cerrado vegetation is converted into sugarcane, Fargione et al. (2008) estimate that conversion would result in a carbon debt, with a 17-year carbon payback time. Since a maximum of 1% of current land use change driven directly by sugarcane in MS may have been from native Cerrado vegetation, the carbon debt generated by land use change is low or non-existent, demonstrating that it is still possible to expand sugarcane production in the state without high carbon impacts.

Figure 7: Estimated Land Use Change (Hectares)



*Notes: Significance *** p<0.01, ** p<0.05, * p<0.1. Confidence intervals at the 90% level. Net result 2 assumes a productivity ratio of one cattle head per hectare (1:1). Net Result 1 sums sugarcane, soybean and corn crops land use change and Net Result 2 subtracts cattle from Net Result 1.*
Source: (Assunção & Pietracci, 2014)

Besides the direct impacts on land use, the construction of new sugarcane mills also generates indirect co-benefits for soybean and corn production. There is a reduction in soybean harvested area of 6.397 hectares, while soybean output remains the same. In parallel, total corn harvested area is unchanged, while total corn production increases. These results indicate an increase in productivity for soybean and corn crops in hosting municipalities.

Overall, this analysis indicates that sugarcane expansion displaces less productive farmers (cattle ranchers in particular) and generates positive co-benefits in other agricultural sectors, particularly in grain production (soybean and corn), increasing their productivity, which means a more intensive land use for cereal crops. Spillovers also happen in non-agricultural sectors.

CONSERVATION EFFORTS IN THE AMAZON[13]

The Brazilian Amazon is an important carbon sink, which can remove carbon dioxide from the atmosphere through carbon sequestration. It also holds unique biodiversity and about 20% of the fresh water that feeds into the Earth's oceans. But the challenge of protecting an area that is equivalent to almost half of continental Europe is equally sizeable.

In Brazil, the Ministry of the Environment oversees the protection of natural resources and enforces relevant government policies. In 2004, a significant change in national environmental protection legislation marked the beginning of a novel approach towards combating deforestation in the Brazilian Amazon.

The Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (*Plano de Prevenção e Controle do Desmatamento na Amazônia Legal,* PPCDAm) was launched and quickly succeeded in slowing deforestation in the Amazon, dramatically reducing its rate from a peak of 27,000 km^2 in 2004 to about 5,000 km^2 square kilometers in 2012.

The PPCDAm consisted of a large set of strategic conservation measures to be implemented as part of a new collaborative effort among federal, state, and municipal governments, alongside specialized organizations and civil society. These actions focused on three main areas: (i) monitoring and law enforcement (with improvements like the introduction of satellite-based monitoring, qualification of personnel, greater regulatory stability, and prioritization of measures on municipalities most affected by deforestation); (ii) territorial management and land use; and (iii) promotion of sustainable practices.

One crucial measure of the PPCDAm was the creation of protected forest areas in strategic locations. One of the most frequently used methods for protecting native vegetation from deforestation is the creation of protected areas, where deforestation is prohibited or heavily regulated towards sustainable exploitation. As showed in Figure 8, under the PPCDAm framework, the locations of newly-created protected areas were strategically chosen to obstruct the advancement of forest clearings moving in from the Arc of Deforestation, or the area of the Amazon where most of the deforestation has occurred. However, although protected areas limited deforestation within their borders, substantial deforestation continued to occur in their immediate surroundings.

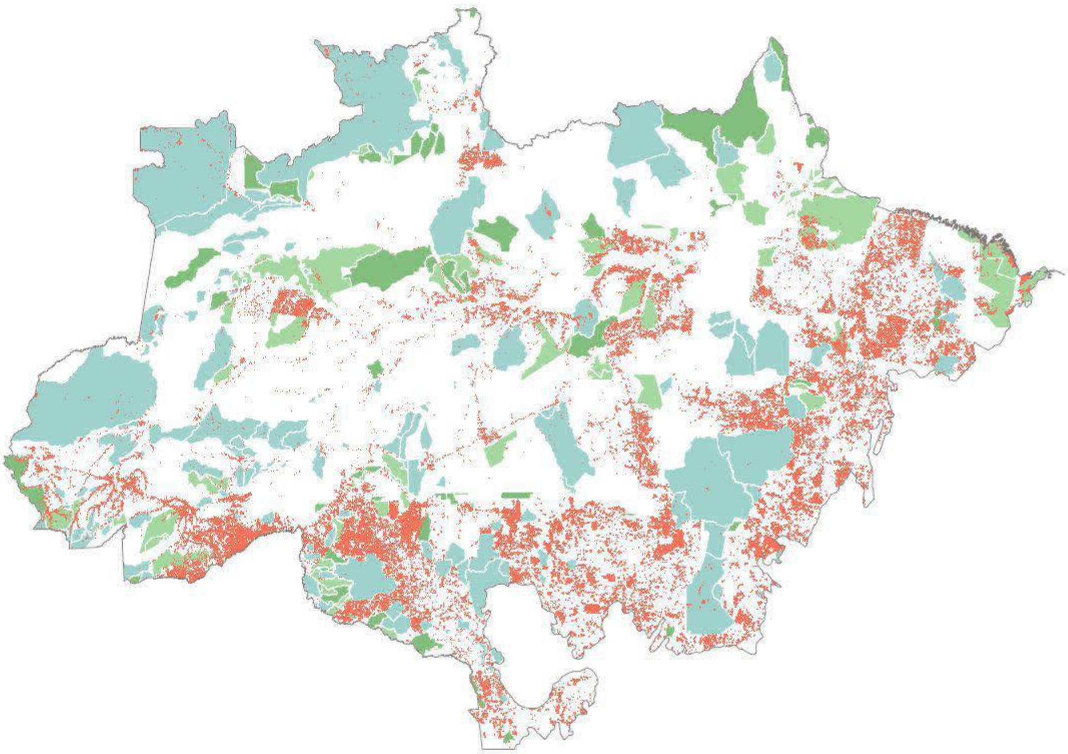
The PPCDAm also promoted a major change in command and control policies, adopting the Real-Time Detection of Deforestation (*Detecção de Desmatamento em Tempo Real,* DETER), a satellite-based system developed by the National Institute for Space Research (INPE), that enables frequent and quick identification of deforestation hot spots. DETER allowed law enforcers to catch offenders red-handed – an aggravating factor for the effective punishment of the crimes. This helped avoid the difficult task of punishing offenders for past deforestation in a place where land and production property rights are often unclear.

In order to assess the effectiveness of the DETER system, Assunção, Gandour, & Rocha (2013) use a panel of 526 municipalities, located partially or entirely within the Amazon biome, to average annual DETER cloud coverage for a municipality as a source of variation in the allocation of the Brazilian Institute for the Environment and Renewable Natural Resources (Ibama) resources that is not driven by deforestation activity. The analysis shows that Ibama is systematically less present in municipalities with greater cloud cover in any given year, and that these municipalities exhibit higher deforestation the following year.

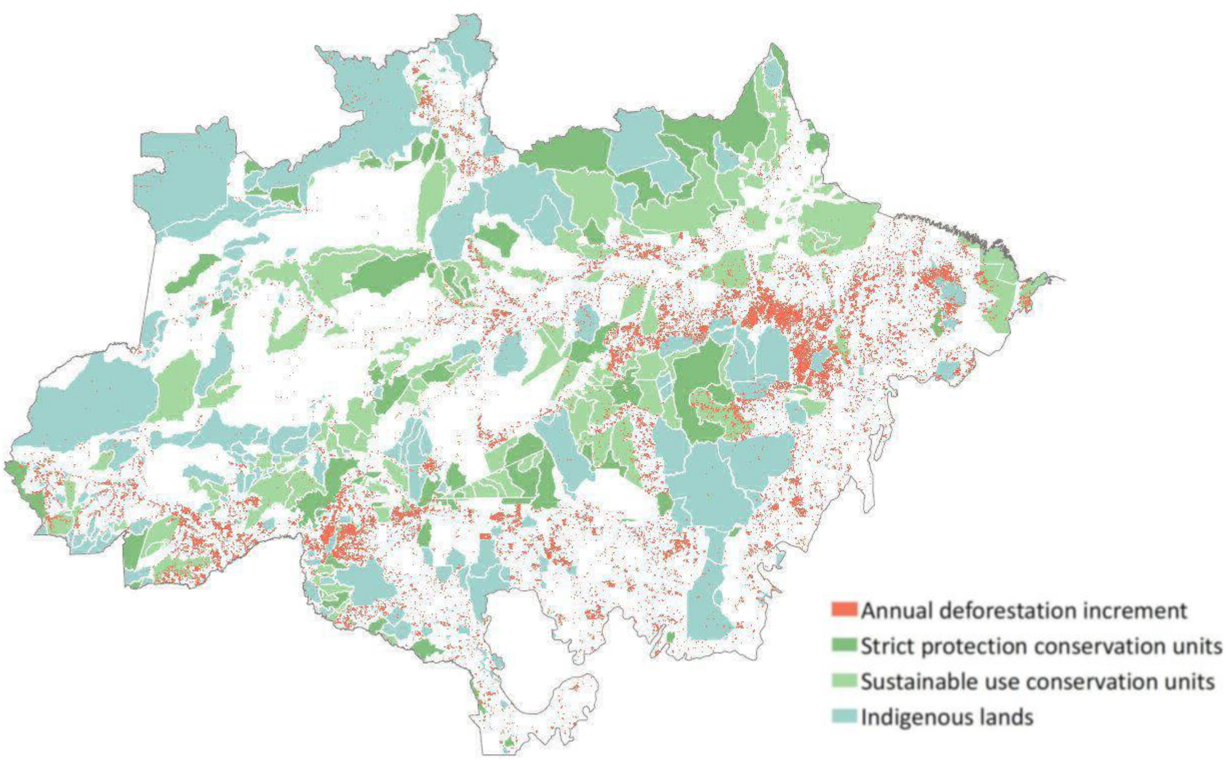
13 This section is primarily based on Climate Policy Initiative (Assunção, Gandour, & Rocha, Recent Brazilian Conservation Policy (2014)

Figure 8: Amazon Protected Territory and Deforestation

a) 2002

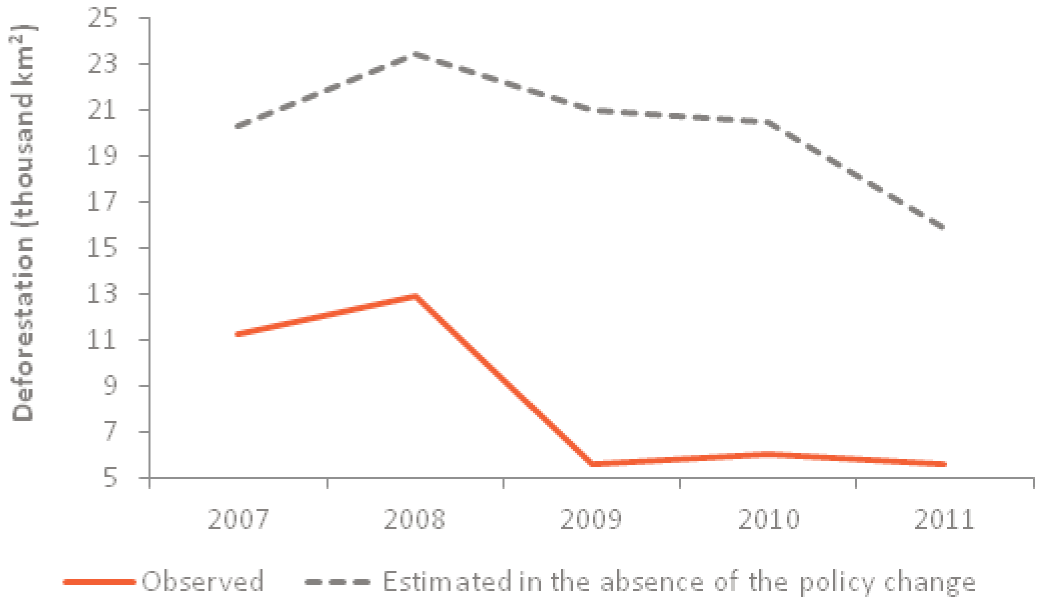


b) 2011



Note: The map shows the location of protected areas and annual deforestation increments in the Amazon biome. Protected areas are divided into strictly protected conservation units, conservation units of sustainable use, and indigenous lands. Data sources: FUNAI (2013), INPE (2013), and MMA (2013).
Source: (Assunção, Gandour, & Rocha, 2014)

Figure 9: Deforestation in the Amazon Biome



Source: (Assunção, Gandour, & Rocha, 2013)

Results indicate that DETER-based monitoring and law enforcement efforts prevented the clearing of over 110,500 km^{2}of Amazon forest area from 2007 through 2011. Deforestation observed during this period totaled 41,500 km^2 – 60% smaller than in the absence of the policy change.

The referred paper also shows that the DETER system works at reasonable costs, both in terms of operational activities and in terms of the immediate opportunity costs. A simple comparison of the sum of Ibama's and INPE's annual budgets with the estimated monetary benefits of preserving forest areas and avoiding carbon dioxide emissions shows that any price of carbon set above 0.84 USD/tCO_2 would more than compensate for the cost of environmental monitoring and law enforcement in the Amazon.[14] Furthermore, the authors find that the policy change had no apparent immediate impact on agricultural production. This suggests that it is possible to protect the native forest, by implementing cost-effective policy measures, without significantly interfering with local agricultural production.

14 Estimations are based on a conversion factor of 10,000 tC/km2 (36,700 tCO2/km2), as established in MMA/DPCD (2011).

3. Looking ahead

Global demand for agricultural commodities continues to increase, driven primarily by expected growth of the global population and the global middle class, especially in emerging and developing economies. To feed a growing and richer population by 2050, the world will need 70% more crop calories than those produced in 2006.[15] Meeting this new demand will create huge opportunities for businesses. However, agricultural expansion is a major driver of land use change which can lead to severe forest degradation and deforestation.

As described in Section II of this paper, Brazil, after emerging from pervasive and substantial misallocation in land use, has demonstrated that the protection of natural capital is indeed compatible with economic growth. Brazil's efforts to expand agricultural production and enhance productivity resulted in positive changes to land use. Brazil also implemented policies aimed at improving protection of natural resources which had no adverse effect on agriculture.

As Brazil seeks to realize latent land use efficiency gains and effective ecosystem protection, it faces a number of challenges and opportunities. In particular, several socioeconomic issues affect environmental protection and agricultural production in the country. Understanding these issues and their driving mechanisms is crucial to better tailoring policy to improve land use.

Section III.1 explores the technical potential for agricultural expansion in Brazil and the related environmental benefits. Section III.2 identifies the challenges and opportunities for increasing agricultural productivity, which include factors like technology dissemination, financial instruments, land rental markets, and infrastructure. Finally, Section III.3 identifies challenges and opportunities in forest protection, especially regarding the protection of native vegetation cleared in small increments on private property, and Brazil's ecosystems beyond the Amazon.

TECHNICAL POTENTIAL[16]

Based on the latest Census of Agriculture, in 2006, pasture occupied nearly 75% of the country's agricultural lands, while crop farming occupied the remaining 25%. This amounted to about 160 million hectares of pasture and 60 million hectares of cropland, for a total of 220 million hectares of agricultural land. This means cattle ranching is the most land-intensive activity in Brazil.

In addition, the productivity of cattle farming can vary widely, even after accounting for geographic characteristics. Most variation in cattle farm productivity is within regions. For example, while the top quarter of the Northern municipalities achieve more than 1.42 heads per hectare (HPH), the bottom quarter is under 0.7, more than a two-fold difference. Even in the region with the least variation in productivity, the Center-West, these thresholds are 0.93 and 1.37 HPH, nearly a 50% difference.[17] While cattle farm productivity has doubled between 1970 and 2006,[18]there is still huge potential for conversion of low-productivity pastureland into higher-productivity cropland.

Furthermore, a significant share of pastures is classified as degraded. Estimations from Assad (2014) indicate that 47 million hectares of degraded pastureland, of which 11 million hectares are in the Amazon, could be recovered. This would generate benefits in terms of carbon stock, CO_2 emissions reductions, and an increase in biomass production, and would reduce the pressure for the conversion of new areas into grassland.

Therefore, it is feasible in Brazil to increase agricultural production without increasing deforestation, and even in a way that reduces greenhouse gas emissions. For instance, (Assad, 2014) estimates that there are more than 40 million hectares of degraded and low-producing pastureland suitable for sugarcane expansion, based on the Map of Agroecological Zoning (ZAE) of sugarcane, which forbids new sugarcane plantations in the Legal Amazon. Replacement of degraded pastures by sugarcane currently occurs in the Center-West, Southeast and South regions, where pastures support less than 0.75 Animal-Unit/ha/year (AU/ha/yr), compared to the national average of 0.9 to 1 AU/ha/year. Conversion of degraded land into sugarcane offers several benefits, including increased soil fertility, increased sequestration of carbon, and reductions in greenhouse gas emissions.

Table 1 shows estimations of CO_2 emissions reductions from (Assad, 2014), based on projections from the Ministry of Agriculture, Livestock and Food Supply (MAPA/AGE, 2013) regarding crop expansion in Brazil until 2023. It indicates that there are opportunities for expanding agricultural production in Brazil without the need to clear new forests, and with the benefit of reducing greenhouse gas emissions.

15 (Searchinger, et al., 2013)
16 This section is primarily based on (Assad, 2014)
17 (Assunção J. , Gandour, Hemsley, Rocha, & Szerman, 2013)
18 (Assunção J. , Gandour, Hemsley, Rocha, & Szerman, 2013)

Table 1: Projected Expansion of Crop Production and Estimated Climate Mitigation Opportunities

	Estimated increase in planted area (2012/13-2022/23) (ha)	Estimated increase in planted area (2012/13-2022/23) (%)	Estimated increase in agricultural output (2012/13-2022/23) (tons)	Estimated avoided CO_2 emissions (2012/13-2022/23) (tCO_2eq/year)
Sugarcane	2.2 million ha	26.5%	41.4%	8 to 21 million tCO_2 eq/ year
Soybean	6.7 million ha	24.3%	21.8%	17 million tCO_2eq/ year
Corn	1 million ha	6.3%	20%	13.7 million tCO_2eq/ year

Data source: (MAPA/AGE, 2013); (Assad, 2014)

KEY CHALLENGES AND OPPORTUNITIES IN AGRICULTURE

Despite a great reduction in large-scale deforestation in the Amazon (discussed in Session II.3), land use changes continue to be a significant driver of deforestation, accounting for the majority of Brazil's total net CO_2 emissions. With a growing agricultural sector and abundant natural resources, Brazil's challenge is to use available land as efficiently as possible.

Intensifying agriculture with higher yields on less land is a possible strategy for preserving natural forest ecosystems and addressing climate change risks, while also addressing food security concerns.

However, there are a number of challenges to increasing agriculture productivity in Brazil. Evidence suggests that improving agricultural productivity depends on several factors: improved technology dissemination, active land rental markets, well-functioning financial instruments, and better quality infrastructure. The remainder of this section analyzes the role of each of these factors and their association with greater farm productivity; the barriers they face for efficient land use; and how the design and implementation of focused policy efforts directed towards improving these factors could greatly contribute to the realization of latent land use efficiency gains.

TECHNOLOGY DISSEMINATION[19]

Technology is associated with greater agricultural productivity in Brazil. However, dissemination of technology has room for improvement. For example, the spread of a no-till farming method called the Direct Planting System (DPS) took place through a process of learning from peers in similar environments.

The use of technology, through the adoption of established agricultural practices such as irrigation, direct planting, rotational grazing, application of lime, and other specific agricultural methods, is associated with greater agricultural productivity in Brazil.[20] However, there are many factors which affect the diffusion of a new technology, and which need to be taken into account by policymakers.

Understanding the channels through which new technologies spread enables the identification of specific policy action opportunities. New technologies are diffused to producers mainly through three key channels: the producers' access to formal education, their access to technical assistance, and learning from peers. Evidence shows that producers' educational levels significantly affect farm productivity. In Brazil, poor average educational levels, particularly among small-scale producers, increases the importance of access to technical assistance as a way to increase a producer's overall ability to learn and implement better agricultural practices.[21]

19 This section is primarily based on (Assunção, Bragança, & Hemsley, High Productivity Agricultural Techniques in Brazil: Adoption Barriers and Potential Solutions, 2013)
20 (Assunção J. , Gandour, Hemsley, Rocha, & Szerman, 2013)
21 (Assunção J. , Gandour, Hemsley, Rocha, & Szerman, 2013)

(Assunção, Bragança, & Hemsley, 2013) investigate the role of social learning – i.e., farmers learning new methods from their peers – in the spread of a no-till farming method called the Direct Planting System (DPS). A technology originally introduced in 1971 in Southern Brazil, the DPS allows the production of higher crop yields at a lower cost, while generating lower carbon emissions. However, despite the advantages of the DPS, and the absence of any significant upfront cost, its adoption rate is still very low in Brazil.

In order to evaluate the importance of social learning in the spread of DPS, the authors explore the impact of a factor that makes it more difficult to learn from peers' previous experience, namely soil dissimilarity. Their results show that soil dissimilarity is systematically related to DPS adoption, which indicates that learning from peers, especially from those whose land shares similar characteristics, catalyzes technological adoption. Further, the authors present evidence that environmental characteristics (such as soil dissimilarity) affect the adoption of a new technology.

These findings suggest that, in order to increase agricultural productivity, it is not sufficient just to invest in innovation, develop business models, and marginally subsidize adoption. Achieving technology diffusion also requires the dissemination of information on new techniques and their associated technologies. Another takeaway is that for public policy to be cost-effective, it should take into account geographic diversity, and prioritize areas where learning from peers is easier and social learning can happen faster.

LAND RENTAL MARKET[22]

An active land rental market offers means to improve land use efficiently by placing more skilled operators on otherwise unused or unproductive available land. Deregulation of land rental markets could contribute to more efficient land use.

Land markets are a vital part of efficient land use because they can significantly increase r farm productivity. When land markets work, either through sales or rentals, they may increase efficiency of land use by placing more skilled operators on otherwise unused or unproductive available land. The capacity to improve land use through land rental markets is particularly important in a setting in which land purchase decisions are made for non-agricultural reasons. This is especially relevant for Brazil – given the country's long history of macroeconomic instability, land ownership in Brazil yields non-agricultural benefits, such as hedging against inflation. In this context, an active land rental market offers the means to improve land use efficiently.

In spite of this, Brazilian land rental markets are underdeveloped in comparison with other countries. Less than 3.3% of Brazilian agricultural land was under lease or sharecropping contracts in the latest World Census of Agriculture, dated from 2006. In contrast, this figure is about 33% in Europe and almost 38% in the United States.

(Assunção & Chiavari, 2014) find that, particularly in a Latin American context, insecurity of well-established property rights, and the lack of effective dispute resolution mechanisms, are part of the reason why land rental markets are underperforming in Brazil.

An additional explanation, explored by the authors, finds imperfections in the legal system. They find that restrictions on rental contracts imposed by Brazilian land and labor legislation, excessive guarantees provided to renters, and the insecurity generated by land reform have created disincentives to the growth of rental markets. Binding non-renounceable clauses for land rental contracts, imposed by the Brazilian legislation, include establishing ceilings on rents, determining forms of payments, fixing minimum limits on the duration of contracts, and granting preemptive rights to renters to renew the contract or purchase the land, among others. The rationale behind these clauses is the assumption that renters need to be protected from the exploitation on the part of the landowner.

The authors suggest that deregulation of land rental markets could contribute to more efficient land use. Current legislation is outdated and it no longer makes sense for Brazil today. The country is a more complex and varied agricultural system, with more capitalized, educated, and experienced renters participating in the market.

This appears to be especially relevant for sugarcane-growing regions, where there is a correlation between functional land rental markets and productivity. Particularly in the case of sugarcane, evidence shows that leasing and sharecropping arrangements are more widely adopted in larger farms, and renters are better off and more educated in the regions where sugarcane is concentrated.

22 This section is primarily based on (Assunção & Chiavari, 2014).

FINANCIAL INSTRUMENTS

About 20% of the regional variation in Brazilian agricultural productivity is related to credit availability, suggesting that greater access to credit could improve productivity. However, care should be taken so that credit availability does not also increase deforestation.

The current instruments available for price risk management are inefficient. Instead of having the government buying out farmers' output as a way of guaranteeing a minimum price, the development of market-based instruments could improve the ability of farmers to deal with risk.

Agricultural production is characterized by relatively long productive cycles, or necessary intervals between planting and harvesting. These long productive cycles, combined with high exposure to weather and price risks, make access to financial instruments crucial to enable rural producers to smooth out shocks. Credit and risk management are therefore very important to agricultural production.

However, credit markets typically suffer from informational problems that lead to credit rationing. Under rationing, the unavailability of credit can become a major barrier to agricultural productivity, especially for farming that requires large capital expenditures. Empirical findings corroborate this rationing scenario. About 20% of the regional variation in Brazilian agricultural productivity is associated with credit availability.[23] This suggests that greater access to credit could improve productivity.

On the other hand, policies that increase the availability of financial resources should be aware of potentially adverse rebound effects. (Assunção J. , Gandour, Rocha, & Rocha, 2013) empirically evaluate the impact of the reduction in the availability of credit implied by Resolution 3,545 on rural loans and forest clearings. [24] They found that the resolution-induced restrictions on credit helped contain deforestation in the Amazon biome. Conterfactual simulations indicate that over 2,700 km^{2}of forest would have been cleared from 2009 through 2011, had the Resolution not been implemented. The analysis suggests that policies that increase the availability of financial resources may lead to higher deforestation rates, depending on the economic environment and the nature of financial resources that are prevailing in the area, and should, therefore, incorporate this potential adverse effect on deforestation.

In addition, farmers with limited access to risk management instruments might be led to invest less than they would in an ideal setting as a means of reducing the volatility of their cash flows. This is especially relevant considering that capital markets, which offer the natural tools for price hedging, are less developed in Brazil than in developed countries.

(Karlan, Osei, Osei-Akoto, & Udry, 2012) provide empirical evidence that credit market constraints and incomplete insurance can reduce investment with high expected profits. Based on various experiments conducted in northern Ghana, where they experimentally manipulate the financial environment in which farmers make investment decisions, the authors find that liquidity constraints are not as binding as typically thought. Instead, they show that risk matters and, in general, hinders investment. Focusing on rainfall insurance, they find that demand for index insurance is strong, and that insurance leads to significantly larger agricultural investment and riskier production choices in agriculture.

(Assunção, Hemsley, & Gandour, 2014) assess the current policy framework for agricultural price support in Brazil, which is still mostly based on direct government intervention, such as guaranteeing a minimum price. They evaluate quantitatively the insurance gains for Brazilian farmers, and they find that this policy offers very limited insurance to farmers.

In particular, the authors show that the current policy seems insufficient to protect farmers from the impact of price risk, in the sense that the value it creates for farmers is small compared to potential gains from insurance. Moreover, they find that the current policy is expensive: in 2013, the federal budget for price risk mitigation totaled BRL 5.4 billion, with over two-fifths of it being destined for government buyouts and storage expenses.

These results suggest that the government should not buy out farmers'output, or decide its destination, since these activities create inefficiency in the markets. Further, direct buyouts, especially when the government purchases the whole output, impose a huge burden on public expenditures. The development of market-based instruments, with possible participation from the government, can free up significant economic potential in Brazil's agricultural sector.

23 (Assunção J. , Gandour, Hemsley, Rocha, & Szerman, 2013)

24 Resolution 3,545 was introduced in mid-2008 and placed a condition on rural credit in the Brazilian Amazon biome. To get credit, borrowers had to present proof of compliance with environmental regulation.

INFRASTRUCTURE[25]

There is ample scope for public policy to improve the quality of infrastructure in the country, and thereby help boost agricultural productivity. For instance, an inadequate road infrastructure fails to efficiently connect products with ports – in some cases representing a near twentyfold increase in costs, with an adverse impact on productivity.

Agricultural producers depend on infrastructure to reach both upstream and downstream markets. In determining producers' access to inputs and consumers, infrastructure alters the return on agricultural production and affects productivity.

Despite being one of the most prominent agricultural producers in the world and an important exporter of agricultural commodities, Brazil suffers from poor infrastructure. In particular, transportation bottlenecks impose a very high cost on agricultural production and thereby reduce agricultural productivity.

(Assunção J. , Gandour, Hemsley, Rocha, & Szerman, 2013) show that there is ample scope for public policy to improve the quality of infrastructure in the country and thereby help boost agricultural productivity. According to their analysis, carrying a ton of soybean from one of Brazil's leading soybean production municipalities to its point of export is almost three times more expensive as it is to carry the same amount of soybean over a similar distance in the United States.

In addition, they find that lacking roads infrastructure keeps production from being exported through more cost-effective ports – in some cases this represents a near twentyfold increase in costs. For instance, the Port of Santarém, located in the North, closer to important consumer markets, is not currently used as an offloading point due to inadequate road infrastructure. Instead, the Southeastern port of Santos is the country's main destination of grain output for export, despite a vessel berthing rate 1,800% greater than the vessel berthing rate at Santarém.

Success in the expansion and operation of transport infrastructure in Brazil depends on a regulatory framework where both private and public sectors cooperate. Recently, there have been some important changes in the regulation of concessions of transport infrastructure covering three key sectors: highways, railways, and ports.

(Rezende & Chiavari, 2014) analyze these changes and discuss some of their impact on investment and operation. They find that, while the specifics are different in each sector, the main driver of these changes seems to be a concern to prevent existing concessionaires to obtain ex-post economic profits. This is done in several ways, such as introducing new rules to make tariffs adjust to changes in cost and demand (as in the case of highways, where factors are explicitly introduced to codify the process by which tolls are to be adjusted to prevent fluctuations in ex-post profits), or introducing competition and eroding local monopoly power (as in the case of railways, where regulation has been changing to unbundle the components of railroad operation). In both cases, the general drift is clear: regulation becomes more complex as the regulator gradually takes the role of the market as a provider of incentives.

If investors fear that there is no stability in the regulatory framework, or if the regulatory framework prevents investors from appropriating economic rents generated by some projects, they will not invest. Or, in order to invest in this environment, they will require subsidies that make up for the regulatory risk.

Indeed, recent changes in transport regulation (and the prospect of future opportunistic behavior by regulators) have been compensated with hidden subsidies through added subsidized funding to foster participation, as demonstrated by the important increase in the releases from the Brazilian Development Bank (BNDES) for infrastructure projects. As a result, the financial burden of the project shifts from users to taxpayers. Under these conditions, apparent success of recent auctions may only indicate excessive subsidizing.

(Rezende & Chiavari, 2014) argue that even when these subsidies are large enough to keep investors interested and allow for new concessions to be awarded, the regulatory changes can have a negative effect on the efficiency of the investment and the quality of expansion and operation of transport infrastructure. This happens because the combined effect of these two policies erodes the incentives of private concessionaires to perform well and to select the best projects, makes projects more costly, and leads to more complex and less efficient relations between concessionaires and regulators.

25 This section is primarily based on (Rezende & Chiavari, 2014).

KEY CHALLENGES AND OPPORTUNITIES IN FOREST PROTECTION

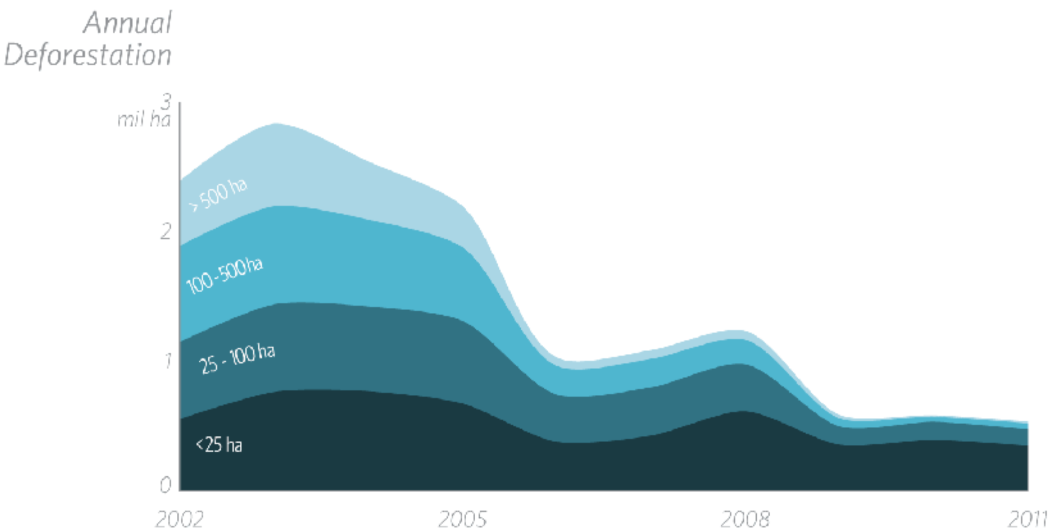
- **On the forest conservation front, in recent years, deforestation has been driven mostly by cutting down forest in small increments. Given differences in how regions have responded to past policy, it will be important to tailor policy according to regional circumstances.**
- **Deforestation outside the Amazon also remains an important challenge. Brazil needs to extend effective monitoring and law enforcement policies over its five biomes, particularly the Cerrado biome.**
- **Improving enforcement of environmental regulation within private rural properties is also essential. Forests occupy about a third of the area of rural private landholdings in Brazil, totaling 100 million hectares of native vegetation within private properties. Effective implementation of the Forest Code, sanctioned in 2012, will be an important challenge.**

The institutional framework for the protection of natural resources in Brazil's public lands and the instruments for applying this framework are more consolidated than those for private protection. Large-scale deforestation in the Amazon biome is addressed by consolidated policy instruments, notably through the creation of publicly protected areas, and by monitoring and law enforcement measures. There is typically very limited deforestation occurring inside Amazon protected areas, but a substantial amount concentrated in their immediate surroundings. In addition, in recent years, deforestation has been driven mostly by the cutting down of forest in small increments. Therefore, small scale deforestation in the Amazon, as well as deforestation outside the Amazon, remain as challenges ahead for the country.

Recent Amazon deforestation trends suggest that the dynamics of Amazon forest clearings may be changing to elude Brazil's Amazon monitoring capacity. In the early 2000s, Amazon deforestation resulted mainly from clearing large contiguous areas of forest. In recent years, however, deforestation has been driven mostly by cutting down forest in small increments. Indeed, the relative participation in annual deforestation of polygons smaller than 25 hectares – precisely those that are not detected by DETER – rose sharply in the second half of the 2000s (Figure 10). In 2002, such polygons accounted for less than a quarter of total annual deforestation; by 2011, this fraction had increased to about two thirds.[26] This recent change in deforestation dynamics presents new challenges for further reducing Amazon forest clearings.

In addition, throughout the past decade, Brazilian conservation policy efforts focused mostly on combating deforestation in the Amazon biome. The vast majority of Brazil's protected areas, in both absolute and relative terms, are found in the Amazon. As shown in Session II.3 above, Amazon forest clearings have slowed significantly in recent years, after escalating in the early 2000s and peaking in 2004, thanks to the significant contribution of conservation policies, combined with declining agricultural output prices.[27]

Figure 10: Amazon Deforestation: Relative Participation by Polygon Size, 2002-2011

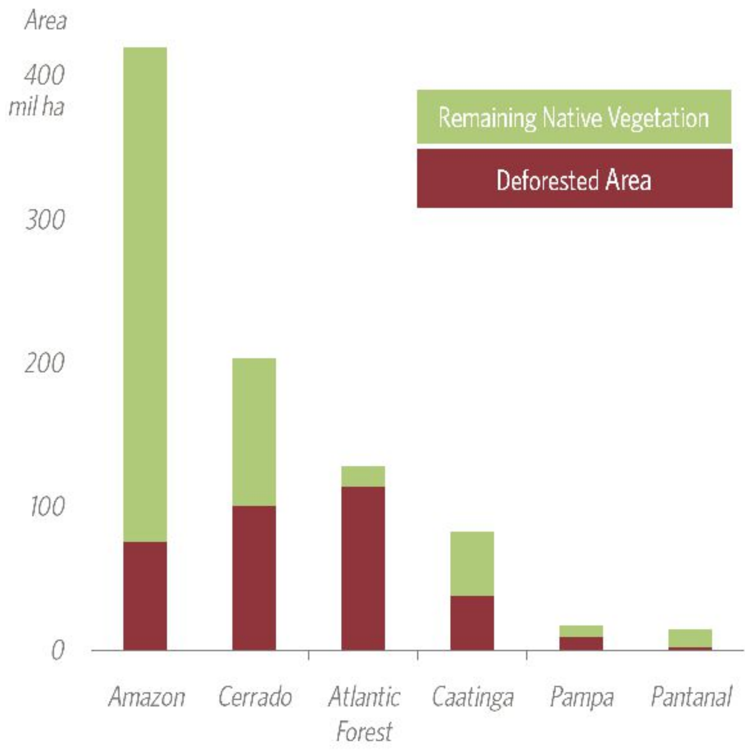


Note: The figure shows the relative participation of each polygon size category in total annual Amazon deforestation. A deforestation polygon is a contiguous deforested area, as captured in satellite imagery. The sample is composed of the Amazon biome. Data source: INPE (2013).

26 (Assunção J. , Gandour, Hemsley, Rocha, & Szerman, 2013).
27 (Assunção, Gandour, & Rocha, Recent Brazilian Conservation Policy, 2014)

Figure 11 shows that all of Brazil's six biomes have seen some extent of clearing of native vegetation. Therefore, combating deforestation outside the Amazon Forest remains an important challenge. In order to achieve this, Brazil needs to extend effective monitoring and law enforcement policies over its other five biomes, which also hold unique biodiversity and serve as carbon stocks. This applies particularly to the Cerrado biome, given that it is highly attractive to agricultural producers, and has already experienced a large extent of cleared native vegetation. Since a substantial share of clearings happening in this biome is legal in light of the Forest Code's regulations, monitoring and law enforcement alone are unlikely to deter large amounts of deforestation in the Cerrado. This reinforces the need for incentive-based policies, such as payment for environmental services, to combat the clearing of native vegetation.[28]

Figure 11: Accumulated Deforestation and Remaining Native Vegetation in Brazilian Biomes



Note: The figure shows total deforested area and remaining native vegetation by biome. Information was collected based on the date of the latest available per-biome estimates for total deforestation: 2009 for the Caatinga, the Pampa, and the Pantanal; 2010 for the Cerrado and the Atlantic Forest; and 2011 for the Amazon. Data sources: FUNAI (2013), IBGE (2013), and MMA (2013).

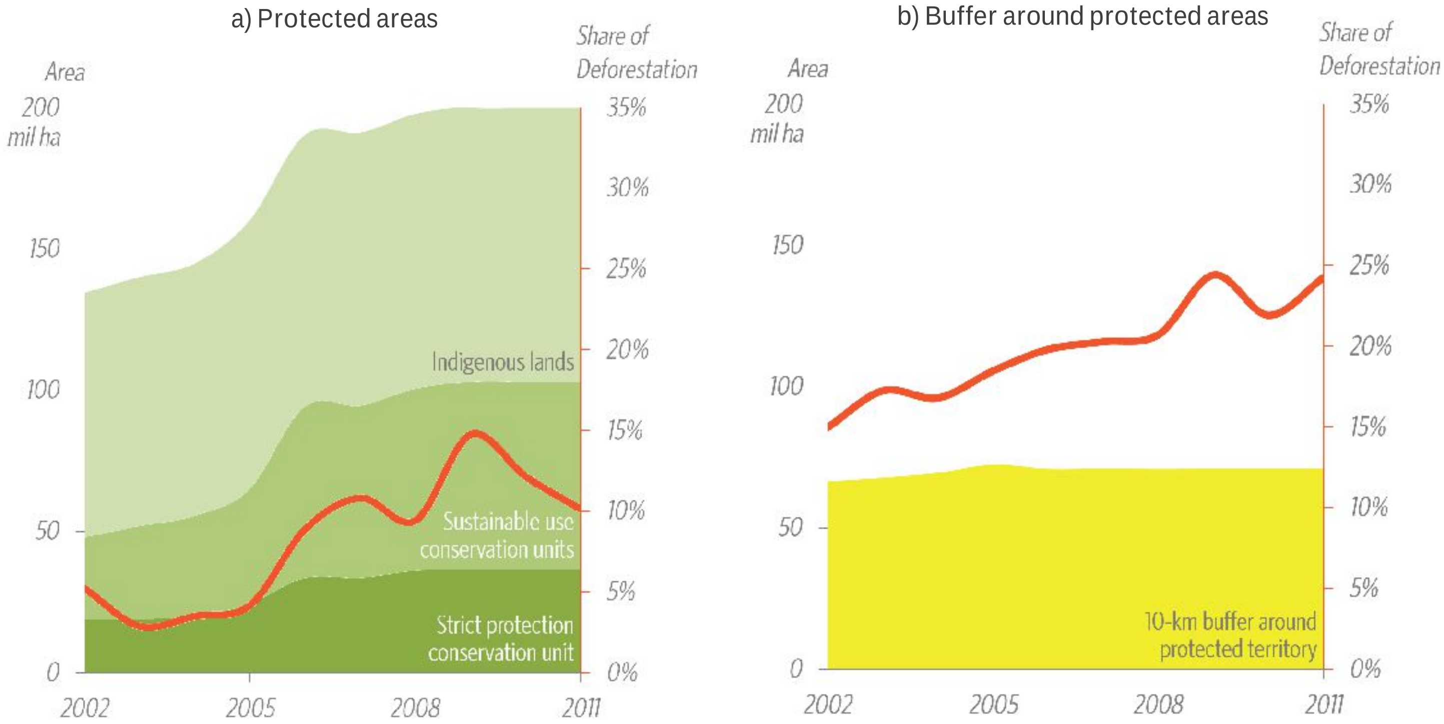
Particular attention should also be placed on leakages from protected areas and land reform settlements (Figures 12 and 13). Figure 12 shows that, although only a small share of total annual Amazon deforestation takes place within protected areas – on average, less than 10%, the share of total forest clearings occurring within 10 km of protected areas rose from 15% to 24% from 2002 to 2011. This is even more striking considering that the total buffer area hardly increased over time, despite the increase in total protected territory.

Also worrying is the increase in the share of total annual Amazon deforestation happening inside rural settlements of the National Institute for Colonization and Land Reform (INCRA) for underprivileged agricultural producers, and within 10 km of them, between 2002 and 2011 (Figure 13). Combined, INCRA settlements and their buffers occupied about 35% of the Amazon biome in 2011, and were responsible for 64% of recorded deforestation in that year, showing that a substantial share of recent deforestation tends to concentrate in and around INCRA settlements.

Finally, improving enforcement of environmental regulation within private rural landholdings is also essential. Forests occupy about a third of the area of rural private landholdings in Brazil, totaling 100 million hectares of native vegetation within private properties. The Brazilian Forest Code establishes the regulatory framework for environmental conservation in private lands, and the Rural Environmental Registry provides the key instrument for enforcing this framework. After over a decade of debate, a new Forest Code was sanctioned in 2012, arguably loosening environmental requirements for private landholders. Although both framework and instrument are in place, effectively using the Rural Environmental Registry to implement the new Forest Code remains a challenge. In addition, uncertainties regarding the enforcement of the Forest Code further compromise entrepreneurs' efforts, increasing their perception of risk and insecurity.[29]

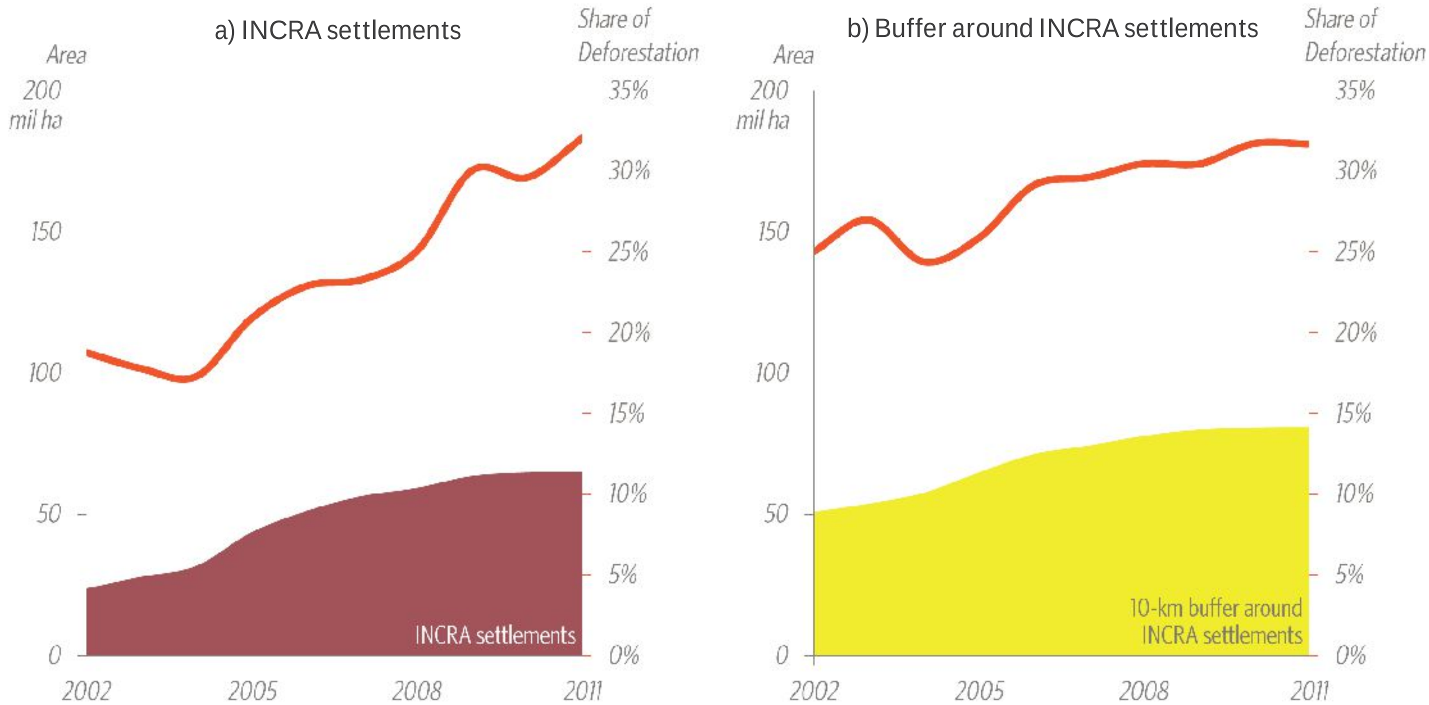
28 (Assunção J. , Gandour, Hemsley, Rocha, & Szerman, 2013)
29 (Assunção, Gandour, & Rocha, Recent Brazilian Conservation Policy, 2014)

Figure 12: Amazon Protected Territory: Size and Share of Annual Deforestation, 2002-2011



Note: Panel (a) shows the total area of protected territory (by category of protection) and the share of total annual Amazon deforestation occurring inside it; Panel (b) shows the total area of a 10 km buffer around protected territory and the share of total annual Amazon deforestation occurring inside it. The sample is composed of the Amazon biome. Data sources: FUNAI (2013), INPE (2013), and MMA (2013).

Figure 13: Amazon Settlements: Size and Share of Annual Deforestation, 2002-2011



Note: Panel (a) shows the total area of INCRA settlements and the share of total annual Amazon deforestation occurring inside them; Panel (b) shows the total area of a 10 km buffer around INCRA settlements and the share of total annual Amazon deforestation occurring inside it. The sample is composed of the Amazon biome. Data sources: INCRA (2013) and INPE (2013)

4. Conclusion

The increasing global demand for food and the need to address climate change risk make it more urgent than ever to protect ecosystems and pursue efficient land use. Brazil, as an agricultural leader in the world and major source of greenhouse gas emissions, is a key player in this context.

This report addresses how Brazil can meet the dual goals of increasing agricultural productivity and protecting natural resources.

The report includes the following key findings:

1. Past experiences and variation in productivity indicate that there is potential for promoting economic growth and improving ecosystem protection simultaneously within Brazil's rural landscape.
   - Past experience shows that it is possible to change land use patterns at scale in a way that achieves both natural protection and economic growth. For example, technology adoption and skilled labor in the Brazilian soybean revolution in the 1970s and 1980s, the investment in sugarcane mills in Mato Grosso do Sul in the 2000s, and the PPCDAm policy efforts starting in 2004, have all increased productivity or conservation without adverse economic effects.
   - The country faces substantial variation in productivity, particularly among cattle ranchers and small farmers. This is the case even within areas with very similar geographical characteristics. Such variation indicates there are opportunities to improve productivity without increased use of natural resources.
2. There is substantial physical potential for increasing agricultural productivity and reducing greenhouse gas emissions by converting degraded pasturelands into crops. For example, Brazil has over 40 million hectares of degraded pastureland outside the Amazon that are suitable for producing sugarcane. In 2006, this represented more than 65% of total Brazilian cropland. Converting this land to sugarcane production can result in higher agricultural value and lower greenhouse gas emissions.
3. Better technology can lead to greater agricultural productivity in Brazil. However, the dissemination of technology has room for improvement. For example, the spread of a no-till farming method called the Direct Planting System (DPS) took place through a process of learning from peers in similar environments.
4. An active land rental market offers means to improve land use efficiently by placing more skilled operators on otherwise unused or unproductive available land. Deregulation of land rental markets could contribute to more efficient land use.
5. About 20% of the regional variation in Brazilian agricultural productivity is related to credit availability, suggesting that greater access to credit could improve productivity. However, care should be taken so that credit availability does not also increase deforestation.
6. The current instruments available for price risk management are inefficient. Instead of having the government buy out farmers' output as a way of guaranteeing a minimum price, the development of market-based instruments could improve the ability of farmers to deal with risk.
7. There is ample room for public policy to improve the quality of infrastructure in the country, and thereby help boost agricultural productivity. For instance, inadequate road infrastructure fails to efficiently connect products with ports – in some cases representing a near twentyfold increase in costs, with an adverse impact on productivity.
8. On the forest conservation front, in recent years, deforestation has shifted from large-scale increments to being driven mostly by the cutting down of forest in small increments. Given differences in how regions have responded to past policy, it will be important to tailor policy according to regional circumstances.
9. Deforestation outside the Amazon also remains an important challenge. Brazil needs to extend effective monitoring and law enforcement policies over its five biomes, particularly the Cerrado biome.
10. Improving enforcement of environmental regulation within private rural properties is also essential. Forests occupy about a third of the area of rural private landholdings in Brazil, totaling 100 million hectares of native vegetation within private properties. Effective implementation of the Forest Code, sanctioned in 2012, will be an important challenge.

BACKGROUND PAPERS

- *Conservation policies in Brazil: effectiveness and new challenges (collaboration with the Núcleo de Avaliação de Políticas Climáticas da PUC-Rio and Climate Policy Initiative)*
- *Technology opportunities in cattle ranching, soy bean, maize and sugar cane in Brazil (collaboration with Eduardo Assad from Embrapa)*
- *The Impacts of Technological Change on Rural Development: Evidence from the Brazilian Soy Revolution*
- *What happens when sugarcane comes to town?*
- *Cattle ranching in Brazil: trends, barriers and market frictions (collaboration with Eustáquio Reis – Ipea)*
- *The Functioning of Land Rental Markets in Brazil: A Missed Opportunity (collaboration with the Núcleo de Avaliação de Políticas Climáticas da PUC-Rio and Climate Policy Initiative)*
- *Challenges and opportunities for improving agricultural productivity through Infrastructure*

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ABOUT THE NEW CLIMATE ECONOMY

The Global Commission on the Economy and Climate, and its flagship project **The New Climate Economy**, were set up to help governments, businesses and society make better-informed decisions on how to achieve economic prosperity and development while also addressing climate change.

The New Climate Economy was commissioned in 2013 by the governments of seven countries: **Colombia, Ethiopia, Indonesia, Norway, South Korea, Sweden and the United Kingdom.** The Commission has operated as an independent body and, while benefiting from the support of the seven governments, has been given full freedom to reach its own conclusions.

In September 2014, the Commission published *Better Growth, Better Climate: The New Climate Economy Report.* Since then, the project has released a series of country reports on the United States, China, India and Ethiopia, and sector reports on cities, land use, energy and finance. It has disseminated its messages by engaging with heads of governments, finance ministers, business leaders and other key economic decision-makers in over 30 countries around the world.

The Commission's programme of work has been conducted by a global partnership of eight leading research institutes: World Resources Institute (WRI, Managing Partner), Climate Policy Initiative (CPI), Ethiopian Development Research Institute (EDRI), Global Green Growth Institute (GGGI), Indian Council for Research on International Economic Relations (ICRIER), Overseas Development Institute (ODI), Stockholm Environment Institute (SEI) and Tsinghua University.

ABOUT CPI

Climate Policy Initiative works to improve the most important energy and land use policies around the world, with a particular focus on finance. An independent organization supported in part by a grant from the Open Society Foundations, CPI works in places that provide the most potential for policy impact including Brazil, China, Europe, India, Indonesia, and the United States. Our work helps nations grow while addressing increasingly scarce resources and climate risk. This is a complex challenge in which policy plays a crucial role.