Policy change or values change? The evolution of the environmental behavior of large-scale soybean producers in Mato Grasso, Brazil

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The Evolution of the Environmental Behavior of Large-Scale Soybean Producers in Mato Grosso, Brazil

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POLICY CHANGE OR VALUES CHANGE?

THE EVOLUTION OF THE ENVIRONMENTAL BEHAVIOR OF LARGE-SCALE SOYBEAN PRODUCERS IN MATO GROSSO, BRAZIL

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Changement de Politiques ou Changement de Valeurs ? L'évolution du Comportement Environnemental des Grands Producteurs de Soja du Mato Grosso au Brésil

Résumé : La production de *commodities* continue de s'étendre dans le monde. Historiquement, ces aires de production ont créé des opportunités économiques mais ont également eu des implications sociales et environnementales discutables. En 40 ans, l'État du Mato Grosso est devenu le principal producteur de soja du Brésil, représentant un quart de la production brésilienne et de 9% de la production mondiale, une expansion fulgurante vivement critiquée pour avoir causé des taux élevés de déforestation. Cette production est le résultat de petits exploitants agricoles qui ont émigré du sud du Brésil dans les années 1970 pour devenir aujourd'hui des grands producteurs de soja. Bien que les politiques environnementales adoptées dans les années 2000 aient réduit la déforestation, l'interaction entre ces politiques, les conditions de marché, la technologie agricole et l'évolution des valeurs des producteurs n'est pas claire. Quels sont les éléments constitutifs du comportement environnemental de ces producteurs et comment expliquer son changement ? Afin d'examiner cette évolution, nous avons choisi une approche multi-méthodes fondée sur une enquête de terrain comprenant 104 entretiens semi-structurés avec des producteurs, ainsi que des données quantitatives (changement d'utilisation des sols et analyse statistique). Bien que ce changement de comportement soit en partie lié aux conditions de marché et aux politiques environnementales, nous démontrons que l'identité techno-culturelle et les valeurs pro-environnementales de ces producteurs ont contribué de manière significative à ce changement. Cette thèse contient des enseignements précieux pour comprendre les mécanismes complexes susceptibles de limiter l'impact environnemental des futures frontières agricoles.

Mots-clés : politiques environnementales, valeurs, soja, grands producteurs, Brésil, Mato Grosso

Policy Change or Values Change? The Evolution of the Environmental Behavior of Large-Scale Soybean Producers in Mato Grosso, Brazil

Abstract: Commodity production keeps expanding around the world. Past areas of commodity production have provided economic opportunities, but mixed social and environmental outcomes. In 40 years, Mato Grosso state has turned into the largest Brazilian soybean producer, representing a quarter of the country's and 9% of the world's production. Criticism of deforestation outcomes abounded. Much of that production was the result of smallholder farmers who migrated from southern Brazil in the 1970s and turned today into large-scale soybean producers. While environmental policies since the mid-2000s contributed to deforestation reduction in the region, the interplay between these policies, market conditions, technology and changing farmers' values is unclear. What constitutes the environmental behavior of these producers and what explains that it evolves over time? To examine this evolution, I used a multi-methods approach based on extensive field research, 104 semi-structured interviews with producers, and quantitative data (land-use change and statistical analysis). Although the behavioral change of large-scale soybean producers has partly to do with market conditions and environmental policies, I demonstrate that their evolution in that regard is the result of a particular techno-cultural identity and pro-environmental values developed over time. This dissertation holds valuable lessons for understanding the complex mechanisms that could limit the environmental impact of future commodity frontiers.

Keywords: environmental policy, values, soybean, large-scale producers, Brazil, Mato Grosso

Mudança de Políticas ou Mudança de Valores ? A evolução do Comportamento Ambiental dos Grandes Produtores de Soja no Mato Grosso, Brasil

A produção de *commodities* continua a se expandir em todo o mundo. Historicamente, áreas para a produção de *commodities* criaram oportunidades econômicas, mas também tiveram implicações sociais e ambientais questionáveis. Em 40 anos, o Estado do Mato Grosso tornou-se o principal produtor de soja do Brasil, respondendo por um quarto da produção brasileira e 9% da produção mundial, um crescimento fortemente criticado por causar altas taxas de desmatamento. Esta produção é resultado do trabalho de pequenos agricultores que migraram do sul do Brasil na década de 1970 para se tornarem grandes produtores de soja hoje. Embora as políticas ambientais adotadas na década de 2000 tenham reduzido o desmatamento, a relação entre essas políticas, as condições de mercado, a tecnologia agrícola e a evolução dos valores dos produtores não é clara. Quais são os elementos constitutivos do comportamento ambiental desses produtores e como explicar as suas mudanças ao longo do tempo? Para examinar essa evolução, este trabalho adotou uma abordagem multi-metodológica baseada em uma pesquisa de campo a partir de 104 entrevistas semi-estruturadas com produtores, bem como dados quantitativos (mudança de uso da terra e análise estatística). Embora mudanças de comportamento estejam relacionadas, em parte, às condições de mercado e às políticas ambientais, revela-se que a identidade técnico-cultural e os valores pró-ambientais desses produtores contribuíram significativamente para essa variação. Esta tese oferece contribuições importantes para entender mecanismos complexos que podem limitar o impacto ambiental das futuras fronteiras agrícolas.

Palavras-chaves: políticas ambientais, valores, soja, grandes produtores, Brasil, Mato Grosso

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List of abbreviations

Acronym	Portuguese	English
ABC	Plano Agricultural de Baixa Emissão de Carbono	Low Carbon Emission for Agriculture Plan
AIA	-	American International Association for Social and Economic Development
APP	Área de Proteção Permanente	Area of Permanent Protection
APROSOJA-MT	Associação de Produtores de Soja e Milho de Mato Grosso	Soybean and Corn Producers Association of Mato Grosso
BASA	Banco da Amazônia	Bank of the Amazon
BNF	Fixação Biológica de Nitrogênio	Biological Nitrogen-Fixation
BVE	-	Bovine Spongiform Encephalopathy
CAN	Colônias Agrícolas Nacionais	National Agricultural Colonies
CIS	-	Combined IAD and SES framework
CAR	Cadastro Ambiental Rural	Rural Environmental Registry (Cadaster)
CPAC	Centro de Pesquisas Agropecuárias dos Cerrados	Cerrados Agricultural Research Center
CPF	Codigo de Pessoa Física	Natural Person Code
CONAMA	Conselho Nacional do Meio Ambiente	National Council on the Environment
CONSEMA	Conselho Estadual do Meio Ambiente	State Council on the Environment
DETER	Sistema de Monitoramento do Desmatamento na Amazônia Legal	Deforestation Monitoring System for the Legal Amazon
EMBRAPA	Empresa Brasileira de Pesquisa Agropecuária	Brazilian Corporation for Agricultural Research
FAMATO-MT	Federação da Agricultura e Pecuária do Estado de Mato Grosso	Agricultural and Cattle-Ranching Federation of Mato Grosso
FC	Código Florestal	Forest Code
FCO	Fundo Constitucional do Centroeste	Constitutional Fund for the Center-West

FEMA	Fundação Estadual do Meio Ambiente	State Foundation for the Environment
FIDAM	Fundo Para Investimentos Privados no Desenvolvimento da Amazônia	Private Investment Fund for Amazon Development
FINAM	Fundo de Investimentos da Amazônia	Investment of Fund of the Amazon
GAP	-	Good Agricultural Practices
GHG	-	Greenhouse Gases
GMO	-	Genetically-Modified Organism
IAC	Instituto Agronômico de Campinas	Campinas Agronomic Institute
IAD	-	Institutional Analysis and Development Framework
IBAMA	Instituto Brasileiro do Meio Ambiente	Brazilian Institute for the Environment
IBEC	-	International Basic Economy Corporation
IBGE	Instituto Brasileiro de Geografia e Estatísticas	Brazilian Institute of Geography and Statistics
ILP	Integração Lavoura-Pecuária	Crop-Livestock Integration
ILPf	Integração Lavoura-Pecuária-Floresta	Crop-Livestock-Forestry Integration
INCRA	Instituto Nacional de Colonização e da Reforma Agraría	National Institute for Colonization and Agrarian Reform
INDEA-MT	Instituto de Defesa Agropecuária de Mato Grosso	Mato Grosso's Agricultural Defense Institute
INTERMAT	Instituto de Terras de Mato Grosso	Mato Grosso's Land Institute
IRI	-	IBEC Research Institute
ISA	Instituto Socio Ambiental	Socio-Environment Institute
IPAM	Instituto de Pesquisas da Amazônia	Amazon Research Institute
LAU	Licença Ambiental Única	Unique Environmental License
LR	Reserva Legal	Legal Reserve
MAPA	Ministério da Agricultura, Pecuária e Abastecimento	Agriculture, Ranching, and Supply Ministry

MATOPIBA	Maranhão, Tocantins, Piauí, Bahia	-
MERCOSUL	Mercado Comum do Sul	Southern Common Market
MMA	Ministério do Meio Ambiente	Environment Ministry
MPF	Ministério Público Federal	Federal Prosecutor's Office
OEMA	Orgão Estadual do Meio Ambiente	State Body for the Environment
PAC	-	Potentially Available Cropland
PIN	Plano de Integração Nacional	National Integration Plan
PMDBBS	Projeto de Monitoramento do Desmatamento nos Biomas Brasileiros por Satélite	Project of Satellite-Based Monitoring of Deforestation in Brazilian Biomes
PNMA	Política Nacional do Meio Ambiente	National Environmental Policy
POLAMAZÔNIA	Pólos Agropecuários e Agrominerais da Amazônia	Agroindustrial and Agromining Poles of the Amazon
POLOCENTRO	Programa Para o Desenvolvimento do Cerrado	Development Program for the Cerrado
PPCerrado	Plano de Ação para Prevenção e Controle do Desmatamento e das Queimadas no Cerrado	Action Plan for the Prevention and Control of Deforestation and Fires in the Cerrado
PPCDAm	Plano de Ação para Prevenção e Controle do Desmatamento na Amazônia Legal	Action Plan for the Prevention and Control of Deforestation in the Legal Amazon
PPG7	Programa Piloto para a Proteção das Florestas Tropicais do Brasil	Pilot Program for the Protection of Tropical Forests of Brazil
PRODEAGRO	Programa de Desenvolvimento Agroecológico de Mato Grosso	Program for the Agro-Ecological Development of Mato Grosso
PRODECER	Programa Nipo-Brasileiro para o Desenvolvimento do Cerrados	Japanese-Brazilian Program for the development of the Cerrados
PRODES	Monitoramento da Floresta Amazônica Brasileira por Satélite	Program for the Monitoring of Brazilian Amazon Forests by Satellite

PROTERRA	Programa de Redistribuição de Terras e Estímulos a Agroindústria do Norte e Nordeste	Land Redistribution Program and Incentives to Agroindustry in the North and Northeast
SEMA-MT	Secrataria Estadual do Meio Ambiente do Mato Grosso	Mato Grosso's State Secretariat for the Environment
SES	-	Socio-Ecological Systems Framework
SISNAMA	Sistema Nacional do Meio Ambiente	National System of the Environment
SLAPR	Sistema de Licenciamento Ambiental das Propriedades Rurais	Rural Property Environmental Licensing System
SPVEA	Superintendência Para a Valorização Econômica da Amazônia	Superintendence for the Economic Development of the Amazon
SUDAM	Superintendência do Desenvolvimento da Amazônia	Superintendence for the Development of the Amazon
SUDECO	Superintendência do Desenvolvimento do Centroeste	Superintendence for the Development of the Center-West
SUDENE	Superintendência do Desenvolvimento do Nordeste	Superintendence for the Development of the Northeast
USAID	-	United States Agency for International Development

Introduction

Ensuring sustainable food production and security in a world made increasingly uncertain by climate change represents one of biggest challenges of the 21st century. In the next decades, and given the current structure of world agriculture, vast new areas of commodity production are likely to appear around the planet to respond to a rising food demand (Schmitz et al. 2014). While not everyone agrees that this type of large-scale production will be needed, albeit desirable, many voices have nonetheless pointed out that increasing food production will be inevitable to ensure food security for the 9 billion (bn) people that will inhabit the planet in 2050 (Nwanze 2017).

New areas, or frontiers,[1] of commodity production are most likely to appear all around the world, but especially in Africa. For instance, African savannas and dry forest regions are thought to be the world's next frontier for large-scale soybean and maize production (Gasparri et al. 2016; Sinclair et al. 2014), a strategy embraced by the African Development Bank (AfDB) (Ojebode 2017). Africa represented 12% of China's outbound agricultural investments in 2014 (Gooch and Gale 2018) and countries like Brazil – projected largest soybean producer and exporter in the world in 2018 – are directly exporting their production model there (e.g. Mozambique, Ghana, etc.)

[1] The "frontier" is a concept first proposed by Frederick J. Turner in his essay "The Significance of the Frontier in American History" presented at a meeting of the American Historical Association in Chicago in 1893 (Turner 2010). At the time, the concept referred to the colonization of the American West: not densely-inhabited areas modified by productive forces, through successive stages, in a unified moving line. The concept has been subject to further development, especially in Brazil. Historian Pierre Monbeig preferred the concept "pioneer front" to that of a unified frontier. He clarified that the expansion of modern societies in such "pioneer areas" is only a temporary process, as they lose their distinctiveness once they develop sufficiently to resemble and function just like the region at the origin of transformations (Monbeig 1952). Others have observed that colonization areas in the Amazon are marked by spatial discontinuity, since colonization settlements seem to present different degrees of advancement and are not necessarily connected to one another or perfectly integrated with the rest of the country (DeFries et al. 2004, Dubreuil et al. 2009; Le Tourneau unpublished; Théry 1996). In this dissertation, I will use the term "frontier" broadly in the sense of "pioneer fronts", taking into account these conceptual developments.

through investments in technology and infrastructure (Cabral et al. 2016; Amanor and Chichava 2016). However, replicating the South American model of commodity production in Africa may raise concerns as much as opportunities.

The challenge of increasing food production is indeed intertwined with that of environmental sustainability. The potential colonization of new agricultural frontiers begs the following question: what do we know about the environmental sustainability of past frontiers of commodity production? In the late 20th century, South America was at the center stage of the expansion of industrial agriculture and commodity production, especially with soybean and corn production in Argentina and Brazil. Despite positive economic and social contributions (Rachael D. Garrett and Rausch 2016; Martinelli et al. 2017; P. Richards et al. 2015; Weinhold, Killick, and Reis 2013b; VanWey et al. 2013), the expansion of these commodities in South America's ecological biomes over the past 30 years has also raised serious environmental concerns, with impacts ranging from deforestation to agrochemical overuse (le Polain de Waroux et al. 2017; Arvor et al. 2017; P. Richards et al. 2015). In the Brazilian Amazon, the gradual and recent intensification of soybean production systems, together with changes in market conditions and environmental policies, have helped mitigate some of these impacts (Macedo et al. 2012; Nepstad et al. 2014) and thus offer a window into the environmental performance of large-scale commodity production areas.

Furthermore, in some (if not the majority) of these new frontiers, large-scale agriculture is positioned to play an important role. Despite a growing academic interest in large-scale agriculture (often conflated with terms such as "industrial agriculture" or "corporate agriculture", as opposed to family farms), not much is known about one of the central actors carrying it out: large-scale

farmers. Although only 2% of the world's farms were larger than 20 hectares (ha) in 2014 (Lowder, Skoet, and Singh 2014), farms over 500 ha represented almost 40% of the total farmland area (FAO 2014). The large discrepancy between farm size distribution and farmland area cultivated sheds light on the blurriness and imprecision of the expression "large-scale" which may cover considerable variation in scale, type of actors, or farm structure. Assimilating such farms too quickly to "corporate structures," with the set of assumptions that such appellation may carry, opens the risk of misunderstanding this type of farming.

To address the dual challenge of environmental sustainability in commodity frontiers and the lack of knowledge about their largest actors, I document in this dissertation the evolution of the environmental behavior of large-scale soybean farmers in the state of Mato Grosso which represented 26.7% of the soybean production in Brazil (CONAB 2019) and 8.6% of the world in 2017 (FAO 2019). In the past 30 years, farmers from Southern Brazil have colonized this region of Brazil situated in between its two largest biomes that concentrate a large amount of native vegetation: the Amazon and the Cerrado. Due to a combination of technological advances, economic conditions, and favorable institutions, this region underwent a spectacular transformation in terms of agricultural production, something thought virtually impossible 50 years ago due the region's acidic soils and tropical climate. Large-scale soybean fields appeared, owned and operated by families of smallholders from the south, as well as large corporations which often were created by farmers or entrepreneurs from the southern states of Brazil. The relatively small group of large-scale farmers that managed to stay in the area (as opposed to those who went bankrupt or decided to leave for other opportunities) had to face biophysical, market, and institutional changes that required them to transform the way they farm. This adaptation went

hand-in-hand with the way they relate to the environment and the way they decide to adopt either conservation practices or agricultural practices that are less harmful for the environment.

This behavioral evolution occurred against a backdrop of complex conditions and understanding how exactly these mechanisms operated is important to drawing lessons for other commodity production areas in South America, Africa, or anywhere else in the world. Since the production models in place in Brazil may be replicated through Brazil's agricultural foreign investment in other countries, or simply because policy-makers and entrepreneurs may be tempted to qualify this case as an "example" of good agricultural practices, it is essential to understand the financial and environmental risk tradeoffs involved in such models if we are to minimize them elsewhere.

1. MOTIVATION

1.1. COMMODITY FRONTIER EXPANSION AND THE CONCERN FOR ENVIRONMENTAL SUSTAINABILITY: THE BRAZILIAN AMAZON EXAMPLE

The expansion of soybean agriculture in the Brazilian Amazon over the last 40 years offers a good window into how multi-dimension, multi-level factors co-interact to produce a diversity of land-use outcomes such as land clearing, crop cultivation, and environmental conservation. Yet it is important to outline from the outset why one may express concern about the expansion of commodity frontiers.

The expansion commodity production in the Center-West and North regions of Brazil started most significantly in the 1970s following the military government's National Integration Plan (*Plano de Integração Nacional – PIN*) (**See Figure 0.1**). Although the Center-West of Brazil

(comprising the states of Mato Grosso, Mato Grosso do Sul, and Goiás) had already experienced agricultural expansion, these colonization policies severely accelerated the pace and extent of the integration of these areas into commodity markets. In the following decades, soybean cultivation expanded mostly into the Cerrado biome, replacing former pastures or savanna type vegetation, which includes vegetation ranging from semideciduous forests to bushes and grasslands. Ranching mostly expanded in the Amazon biome, replacing mostly dense ombrophile forests but other types of vegetation as well.[2] The modernization of the economy in the 1990s resulted in increasing the role of Brazil in commodity export markets, accelerating the expansion of these activities onto these two Brazilian biomes.

[2] The Amazon biome covers an area of 4 million (m) square kilometers (km^2) in Brazil. It is essentially composed of dense ombrophile forests but also present savannas and other land covers to some degree. The Cerrado biome, which has received less national and international attention than the Amazon (Overbeck et al. 2015; Klink and Machado 2005) covers approximately 2 m km^2 in Brazil. It presents a diversity of vegetation covers ranging from semi-deciduous forests to savannas and grasslands. These areas have been heavily cleared due to the expansion of agricultural activities, mainly by cattle-ranching (0.8 million km2 for the Amazon biome, 0.9 million km2 for the overall Cerrado biome) (INPE 2018a, 2018b; Carneiro et al. 2018), jeopardizing the well-being of ecosystem services supporting the Brazilian economy (Joly et al. 2018).

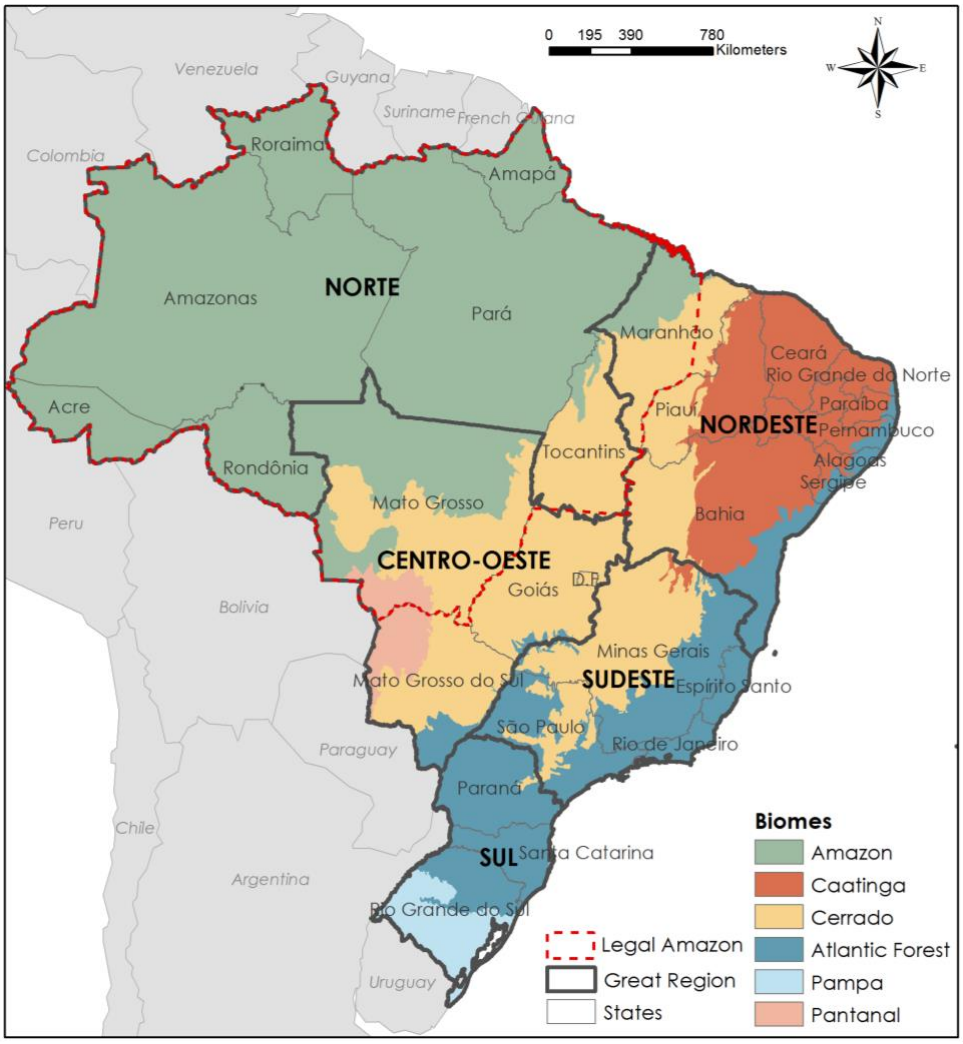


Figure 0.1 Political boundaries and biomes of Brazil. The state of Mato Grosso is entirely encompassed in the Legal Amazon region and has a small significant share of the Pantanal biome in addition of the Amazon and Cerrado biome.

The replacement of 20% of the Amazon's and 45% of the Cerrado's native vegetation by commodity production[3] as of today has logically raised major concerns, both nationally and internationally, especially about the Amazon rainforest (Carneiro and Costa 2016; Strassburg et al. 2017; Nepstad, Stickler, and Almeida 2006). The degradation of the Brazilian Amazon[4] is especially worrying since the region represents one of the largest carbon stocks on Earth (an

[3] Not all human activities in both biomes are due to commodity production, but the overwhelming part is.

[4] The "Brazilian Amazon" refers here to a specific territorial administrative unit, the Legal Amazon, created in 1953 by the Brazilian government to oversee the distribution of development subsidies for the colonization of the Center-West and Northern regions of Brazil. It covers 9 states and contains most of what is known as the Brazilian Amazon rainforest. It includes the 4 million (m) square kilometers (km2) of the Amazon biome and 750,000 km2 of the Cerrado biome.

estimated total of 58.62 ± 12.81 billion (bn) tons of carbon (C) is contained in this region's biomass) and plays a key role in the regulation of rainfall patterns for the whole South American continent (Zeri et al. 2014). The rapid removal of native vegetation in the Brazilian Amazon has resulted in numerous environmental impacts such as changes in precipitation variability and extreme rainfall events, a longer dry season affecting tree mortality, stream warming affecting fish species, and the release of vast amounts of carbon (Nobre et al. 2016; PBMC 2013; Macedo et al. 2013).

The Cerrado biome, in particular, has been converted to land-use and degraded faster than the Amazon biome. Strassburg et al. estimate that "between 2001 and 2011, deforestation rates in the Cerrado (1% per year) were 2.5 times higher than in the Amazon" (Strassburg et al. 2017: 1). Eight (of 12) major river basins in Brazil have springs located in the Cerrado biome, and some major underground water reserves are there as well (for instance, the Guarani Aquifer which is one of the largest aquifers in the world) (Durigan 2012).[5] Although the two biomes together represent one of the world's biodiversity hotspots, with a high concentration of tree species (i.e. containing 11,000-16,000 plant species) (Hubbell et al. 2008; Steege et al. 2013; Forzza et al. 2012) and a diverse set of mammals, avifauna, reptilians and invertebrates (Klink and Machado 2005), the Cerrado alone contains 4,800 unique plant and vertebrate species (Strassburg et al. 2017).

Yet, as deforestation rates decreased in the 2000s following the enactment of public policies, pressures from commodity markets, and the intensification of soybean agricultural production, other environmental impacts started to raise further concern (Nepstad et al. 2014; Arvor et al. 2017;

[5] The springs of the Araguaia-Tocantins, São Francisco, Amazônica and Prata river basins are located in the Cerrado for instance.

VanWey et al. 2013). Modern soybean production relies on a large amount of agrochemicals to fight off an ever-increasing number of pests, soil diseases, and invasive species (Contini et al. 2018). Brazilian agriculture in general is already a disproportionately large consumer of agrochemicals, representing 20% of the world's agrochemical consumption (Brazil represented 84% of Latin American sales in 2007) (Bombardi 2017). Soybean agriculture represented 52% of all agrochemical sales in the country in 2015.[6] Bombardi (2017) reports that the average agrochemical use in the Center-West (Mato Grosso, Mato Grosso do Sul, and Goiás) oscillates between 12 and 16 kg/ha, well above the national average of 8.33 kg/ha. This heavy reliance on modern chemical inputs bring fears of health contamination and river pollution (Arvor et al. 2017). Although these impacts may not be as high as expected in terms of nutrient leaching compared to similar problems in temperate climates (e.g. for river pollution, see Neill et al. 2013, 2017), the effects of other agrochemicals like pesticides are very concerning, as 1,785 cases of poisoned intoxicated individuals were recorded in the Center-West between 2007 and 2014.[7]

It is thus particularly concerning if the model of soybean commodity frontier expansion of Brazil is exported *as is* to other commodity frontiers in the world. For instance, if deforestation in the Cerrado biome keeps increasing according to a business-as-usual scenario, "the anticipated conversion will emit up to 8.5 Pg CO2e (petagrams of CO2 equivalent) — over 2.5 times all the emissions reductions achieved in the Amazon between 2005 and 2013," period during which deforestation rates decreased by about 80% of its historical peak (Strassburg et al. 2017). The full

[6] This number jumps up to 72% if we include maize and sugarcane (Bombardi 2017).

[7] This number needs to be put into context. The Health Ministry indicated that for the 2007-2014 period, there were more intoxicated persons in the South (5,547 persons), Southeast (5,473) and Northeast (4,005) than in the Center-West (1,785) and North (859) (Bombardi, 2017). The population of the Center-West (11 m people) is however far less than the population of the South (20 m people), the Southeast (70 m), or the Northeast (46 m).

set of environmental impacts linked to the soybean expansion was the result of the land-use choices of thousands of individual actors who went through different stages of agricultural practices and strategies. Understanding how these practices evolved together with a variety of factors (technological, economic, and institutional) and how their visions have shaped (and were shaped by) these practices is therefore a major challenge for projecting what future commodity frontiers can look like.

1.2. Initial puzzle: Large-scale producers and Mato Grosso's transition from high to low deforestation

Starting in the 1970s, groups of smallholder farmers from South Brazil started colonizing two plateaus located in Center-Northern and Western Mato Grosso. Private colonization firms (Jepson 2006a; Dubreuil, Bariou, Passos Dos, et al. 2005), but also entrepreneurs and individual realtors, sold them individual land lots while the federal government created colonization policies supporting the agricultural development in this area, when they did not bring farmers themselves through public colonization settlements (e.g. Lucas do Rio Verde; See Rausch 2013). They especially settled along the BR-163 highway linking Cuiabá (the state capital) and Santarém (Pará state capital), composed today of municipalities such as Sorriso, Nova Mutum, Lucas do Rio Verde, and West from there in the Chapada dos Parecis, which is covered today by the municipalities of Campo Novo do Parecis, Sapezal and Campos de Júlio. Contrary to the dominant pattern of Amazon colonization, which relied on cattle-ranching, farmers in these areas of Mato Grosso cleared large areas of native vegetation to start mechanized agriculture.

Importantly, they settled in an area of transition vegetation sitting at the edge of the Amazon and the Cerrado biomes, which represented a mosaic of different vegetation types ranging from dense

forests to grasslands, a characteristic of two biomes in constant flux with the dynamic expansion and retraction of Amazon forests into the Cerrado biome (Ackerly et al. 1989; Marimon et al. 2014). Despite important soil quality issues, these areas presented ideal conditions for agriculture. These vast plateaus covered in easy-to-clear grasslands and savannas, had a topography especially suitable for mechanization, and presented a clearly-defined 6-month rain season. In addition, the area contained large forest patches marking the proximity with the Amazon biome.

It turned out that these land cover characteristics had two fundamental implications for the way deforestation was assessed. First, farmers cleared a lot of non-forest Cerrado vegetation to settle their rural properties, which was made quicker and in a least costly way that forests. Despite not being forests, the resulting perception by the general public was that these farmers deforested enormous extents of native forests. Second, and most importantly, the satellite-based deforestation monitoring system of Brazil, the PRODES,[8] only detected the clearing of forests in the Amazon biome.[9] As a result, until the Brazilian government started a native vegetation monitoring program for the Cerrado after 2009, most of these producers were effectively "off the hook" of environmental policy enforcement.

Once the difficulties of the early stages of this frontier (acidic soils, non-adapted crops) were overcome through technological innovation, farmers started planting soybeans. The rising international demand for this crop in the 1990s spurred the development of soybean farming in Mato Grosso which increased the pressure on forests (Nepstad, Stickler, and Almeida 2006). The

[8] Program for the monitoring of Brazilian Amazon forests by Satellite. In Portuguese: "Monitoramento da Floresta Amazônica Brasileira por Satélite."

[9] It also sporadically detects deforestation in the Cerrado biome, but very imperfectly. See Chapter 4.

high deforestation rates of the 1990s and 2000s (mostly caused by the expansion of cattle-ranching) spurred domestic and international concern over the fate of the Amazon and led the federal government to reinforce environmental policies through stricter regulation and better enforcement (Pires 2014). Deforestation rates subsequently dropped in these areas while soybean production kept growing, demonstrating the movement toward intensification operated by farmers in the area (Macedo et al. 2012). Since 2005, the deforestation rates in these two soybean production areas of Mato Grosso have been modest or non-existent despite the soybean production boom, while other areas of Brazil, which have received less scrutiny, were massively converted to soybean production.

1.2.1. Policies or Markets?

The initial questioning around this dissertation research project was: Why did farmers transition to this state of almost zero-deforestation despite booming soybean production? This questioning was further complicated when it appeared many of these farmers were using agricultural practices that would be considered part of Conservation Agriculture (CA) such as no till systems (Pittelkow et al. 2015). Were we observing an example of "green" or "environmentally-friendly" modern agriculture? If yes, why would these farmers choose to produce this way while preserving the remainder of forests?

The puzzle of what "caused" this behavior on the part of soybean producers was therefore the starting point of this research. Soon, I was inclined to look into the "usual suspects" and turned my attention to the environmental policies enacted by the government. The 2000s had seen a reinforcement of state capacity in response to extremely high deforestation rates. In 2005, new satellite imagery technologies permitted the daily monitoring of deforestation while only annual

data existed previously.[10] This "game changer" in deforestation monitoring supported the strengthening of the enforcement capacities of the federal Environmental Agency (IBAMA) by the federal government in 2004 which established an action plan to fight deforestation. Cleared forests subsequently went from 27,772 km2 in 2004 to 4,571 km2 in 2012, a spectacular 83.5% drop in deforestation rates.

Nonetheless, it quickly appeared that attributing all the deforestation reduction to policies alone did not make much sense to explain why soybean producers abruptly stopped clearing land. A few elements challenged the narrative of successful environmental policies. First, soybean producers had been struck by a financial crisis in 2004-2005 which had seen the price of soybean drop, the exchange rate between the U.S. dollar and Brazilian-real turn to their disadvantage (a key variable since most of the soybean produced is exported on international markets) (P. Richards et al. 2012), and the gradual appearance of new plant or soil diseases hindering yields (soybean cyst nematodes and the Asian soybean rust) (Contini et al. 2018). This crisis happened after a period of extremely favorable production conditions (price, exchange rate, credit flowing, etc.) which led to unprecedented expansion over native vegetation (Morton, DeFries, Shimabukuro, Anderson, Arai, Espirito-Santo, et al. 2006; Andréa Aguiar Azevedo 2009). As the soybean economy crashed with the weakening of these factors, clearing necessarily reduced. Producers had first to recover from their large losses, if not go bankrupt. This could have explained why deforestation rates dropped in the area, however most analyses at the time based their observation on official deforestation rates provided by the National Institute for Spatial Research (INPE), and therefore mostly

[10] The DETER program of daily monitoring of deforestation was launched in 2004, tested in 2005, and fully operational in 2006 (Assunção et al. 2017). Chapter 3 covers environmental policies and the monitoring of deforestation in greater detail.

monitored forests located within the Amazon biome, not the Cerrado biome. This was therefore problematic to explain the behavior of soybean farmers since much of the area of interest belonged to the Cerrado biome.

Furthermore, as economic conditions started to improve in 2006 and get back to normal, deforestation did not increase again. How could one assume that economic conditions influenced deforestation if it could explain only a *reduction* in deforestation but not an *increase*? One may object that this absence of deforestation increase could be explained by the fact that environmental policies started to be increasingly enforced in the post-2004 period, with fewer "immediate" effects in 2004. Nonetheless, and as I noted above, much of the focus of federal government's enforcement operations in Mato Grosso concerned areas of the Amazon biome dominated by forested landscapes actively converted into cattle-ranching and, to a lesser extent, to soybean fields. It thus appeared clear that, at the least, an explanation based *solely* on environmental policies or market conditions was at best incomplete. The puzzle thus went on.

1.2.2. Small versus Large-scale deforestation: the role of large-scale producers

An additional layer to the puzzle came from various studies pointing out that the share of large as compared to small deforestation patches in the Amazon had reduced very significantly starting in 2006 (Assunção et al. 2017). The literature on the Amazon has been divided about the respective role of large landowners as opposed to smallholders in deforestation, and this divide also finds its roots in the public debate over Amazon deforestation. Early studies revealed the important role of large-scale cattle ranchers, attributing more than 70% of deforestation to large and medium rural

properties with this type of land-use (Philip M. Fearnside 1993, 2005a). Confirming such assessments, recent studies point out that areas dominated by large-scale properties tend, overall, to hold less forest cover than areas dominated by small properties (which have been responsible for only 16.3% of all past deforestation) (Godar et al. 2014a). In a study around the TransAmazon highway, authors however found that, if the absolute amount of deforestation tends to increase proportionately with property size, large properties tend to retain a greater share of native vegetation than small properties (< 100 ha) overall (Godar, Tizado, and Pokorny 2012), a relationship which is not consistently confirmed at the regional-level (Legal Amazon region) depending on the data used (Godar et al. 2014a; Michalski, Metzger, and Peres 2010).[11] If confirmed elsewhere, this relationship between property size and forest cover is important if not critical for the maintenance of ecosystem services. In Mato Grosso, for instance, it is estimated that properties over 1,000 ha contain 80% of the carbon stock located on private rural properties (P. Richards and VanWey 2016).[12]

Yet, what was important for the present puzzle was that this deforestation pattern between smallholders and large-scale landowners changed over time, especially around the mid-2000s, exactly as environmental policies and market conditions were changing. According to Godar et al.

[11] In a 2014 study, Godar et al. found that areas dominated by smallholders tended to have more forest cover than areas dominated by large properties. Partly explained by the fact that such small properties are typically dominant in more remote and densely forested areas, the authors insist that: "However, the fact that we observed similar differences in forest condition between areas dominated by different actors for all Amazonian states suggests they do reflect consistent differences in actor-specific land-use patterns" (Godar et al. 2014a: 15594). Soler et al. (2014) found the opposite result but focused on Mato Grosso and Rondônia.

[12] Richards et al. (2014) thus do not find that small properties are associated with less clearing than large ones, but the contrary. One may speculate that this result, different from Godar et al. (2014) who find that smallholders preserve more, comes from the fact that Richards et al. used another property measurement (the CAR, see Chapter 3) instead of the property size measured by the agricultural census. As the CAR contains mostly unverified property data, there may exist an over-declaration of large properties on forested areas, while these might simply not exist or have not been exploited yet. However, Stefanes et al. (2018) got results consistent with Richards et al. (2014) in Mato Grosso do Sul, using the CAR.

(2014a), areas dominated by very large properties (> 2,500 ha) were responsible for 30.1% (33,041 km^2) of the total deforestation between 2004 and 2011, while those with small properties (<100ha) represented only 21.1% (12,789 km^2) of the same total. However, based on a scenario which assumes that deforestation rates would have been the same for the 2004-2011 period as those for the 1996-2005 period, the researchers found that the actual contribution to deforestation by very large landholders reduced much more than that of smallholders: "In fact, the contribution to annual deforestation for areas dominated by very large properties dropped by a maximum of 63% between 2005 and 2011, whereas that of smallholders increased by 69% for the same period" (Godar et al. 2014a: 15593). Hence, despite remaining the major contributors to deforestation, areas dominated by large landholders had reduced deforestation in greater proportion than any other category.

This behavioral shift was particularly interesting insofar as it may have indicated that the drivers of deforestation (and its inhibitors) are different depending on actor types (here defined by size). However, the major limitation of these studies was that they based assessments of producer behavior on data covering only the Amazon biome, limiting the debate between small and large producers with observations valid only for a small amount of producers in the Brazilian Amazon, excluding soybean producers almost entirely from the analysis (since the overwhelming majority of them are located in the Cerrado biome).[13] Most studies did not address whether the difference in land-uses across properties (cattle-ranching versus soybean production) may also be one reason for deforestation reduction. Furthermore, the differences in the conclusion can be partly explained by the scope of each study, as some focused on the entire Legal Amazon (which present

[13] To be entirely fair, the PRODES was the only official deforestation data available at the time for most of these studies.

heterogeneous land-uses) or an entire state (which results in hiding much heterogeneity between the tenure structure of different Legal Amazon states).

Two elements therefore stood out from this initial puzzle: (1) Environmental policies may have affected large-scale properties dominated by ranching activities differently than those dominated by soybean cultivation, since they are both subject to different market and monitoring conditions (Gibbs et al. 2016, 2015; P. Richards et al. 2017); (2) Determining the respective response of small versus large landowners to environmental policies requires an examination of the specific behavior of large-scale soybean producers as well.

2. STATEMENT OF THE RESEARCH PROBLEM

Determining the mechanisms driving the sustainability (and forest conservation) of specific actors remotely with satellite-based land-use analysis may have proven incomplete. Then came the following idea: why not go there and ask them? It is the defining mark of social and behavioral sciences, as compared to other research approaches, to look at the world through the eyes and the words used by local actors responsible for the phenomenon of interest. It assumes that the actors' own interpretation of their actions has mattered in the formation of the studied outcome and will likely matter for the way it will change in the future. As Bourdieu famously put it in *Distinction: A Social Critique of the Judgment of Taste*:

> *"One has explained nothing and understood nothing by establishing the existence of a correlation between an 'independent' variable and a 'dependent' variable. Until one has determined what is designated in the particular case, i.e., in each particular relationship, by each term in the relationship (…), the statistical relationship, however precisely it can be determined numerically, remains a pure datum, devoid of meaning"*[14] *(Bourdieu 1984: 18)*

[14] The full quote is the following: "One has explained nothing and understood nothing by establishing the existence of a correlation between an 'independent' variable and a 'dependent' variable. Until one has determined what is

By allowing process-tracing and causal-process observations (Mahoney 2010), qualitative fieldwork has the potential to identify "hidden" variables and steps into landowners' decision-making affecting a given situation, both of which neither appear in the "eyes" of the satellites (i.e. changing land covers) nor in numbers recorded into an agricultural census or other types of quantitative data. By supplementing field-based qualitative evidence with quantitative evidence, multimethod approaches can provide a space where researchers can navigate between theory testing and theory development, taking advantage of the insights from both traditions of social inquiry.

In less than forty years, farmers from humble origins had converted this area of Mato Grosso into the leading soybean production area of Brazil by going through very distinct periods of agricultural development. They endured successive challenges to their agricultural model, from the very start when, in the early stages of colonization, their rice plantations failed after only 2 or 3 years. In the 1980s, they kept producing soybeans despite the vanishing of federal incentives supporting agricultural development (linked to a broader economic crisis in Brazil). In the 1990s, rising production costs and the exhaustion of soils due to soybean agriculture also pushed them to abandon the idea of tilling the soils, and they started embracing no till systems. These modifications in production strategies demonstrated the capacity of producers to adapt to new biophysical, institutional, and economic conditions.

designated in the particular case, i.e., in each particular relationship, by each term in the relationship (for example, level of education and knowledge of composers), the statistical relationship, however precisely it can be determined numerically, remains a pure datum, devoid of meaning. And the 'intuitive' half-understanding with which sociologists are generally satisfied in such cases, while they concentrate on refining the measurement of the 'intensity' of the relationship, together with the illusion of constancy of the variables or factors resulting from the nominal identity of the 'indicators' (whatever they may indicate) or of the terms which designate them, tends to rule out any questioning of the terms of the relationship as to the meaning they take on in that particular relationship and indeed receive from it" (Bourdieu 1984: 18)

These changes in conditions also caused a reconfiguration of their relationship to the environment, that prompted more questions about the exact scope of changes in their land-use decision-making. The colonization of these areas of Mato Grosso caused extensive land clearing, and the expansion of soybean agriculture in the 1990s and early 2000s was linked to further clearing. Yet, after land clearing slowed down significantly in the mid-2000s, this did not mean the end of environmental (and health) concerns. The modernization of soybean agriculture relied on the extensive use of chemical fertilizers. The increasing appearance of pests of various kinds required producers to spread pesticides more heavily. As a result, if their relationship to the environment was to be discussed, the inquiry could not be circumscribed to land clearing aspects.

The puzzle appeared to revolve around the following question: What explains the evolution of the environmental behavior of these producers? By environmental behavior, I mean the characteristics of the human-environment interaction resulting from farmers' decisions, regardless of the intent of this decision. Farmers define the terms of this relationship when they make decisions about preserving native vegetation on their property as much as when they make decisions about crop production. In a way, this is a single land-use decision with dual implications. Production decisions are the other side of the coin of conservation decisions, and there may be more than simply two dimensions to this question. It is also often difficult to distinguish the influence of normative aspects (environmental values, attitudes, worldviews) as opposed to economic priorities in the evolution of production and conservation decisions. A related puzzle to the one cited above is therefore: how much can the changes in agricultural practices and

environmental behavior be attributed to the evolution of environmental values instead of economic factors?

Was the behavioral change observed in Mato Grosso over thirty years the result of changing policies, economics, and biophysical limits, or something else? If changes in their environmental behavior were caused by all of these factors, what was the respective role of each one? Setting out to answer this question is no small task. Further daunting is the question of the extent to which farmers had a choice to follow alternative paths of production and environmental impact. Did farmers have agency in the transformation of their production systems and their associated environmental impacts, or were they passive agents, "prisoners" of larger structures imposing this path?

After all, the very existence of this leading soybean producing region rested upon a unique combination of variables and conditions not replicated elsewhere in Brazil. Despite common agricultural colonization policies for the entire Amazon and Cerrado region,[15] it is the combination of favorable climate and biophysical conditions, technological advances in soil management and soybean varieties, presence of infrastructures and colonization firms, and a group of highly-motivated farmers in these two areas of Mato Grosso that resulted in the creation of a hotspot of soybean production.[16] It is therefore the simultaneous encounter of biophysical, technological, institutional, economic and social (individual and group) factors that led to the formation of the soybean production areas. This "case" provides the adequate backdrop to examine the relative

[15] One may argue that Mato Grosso took advantage of policies existing for both regions since the state is situated at the edge of both biomes and policies had blurred scopes of application.

[16] The story is obviously more complex, as I will develop in the dissertation, but simplification was needed here to give the reader the intuition behind the research questions.

agency that farmers had in the process of agricultural colonization. Such a colonization is moved by forces greater than individuals, but that story is ultimately made up by a multiplicity of individual stories and their interconnectedness with one another.

3. RESEARCH QUESTIONS: WHAT CONSTITUTES SOYBEAN PRODUCERS' ENVIRONMENTAL BEHAVIOR AND HOW HAS IT EVOLVED?

This dissertation sets out to examine the environmental behavior of large-scale soybean producers in Mato Grosso from 1985 to 2015, a period corresponding to the early stages of the colonization of the Amazon-Cerrado areas of the state to a consolidated leading soybean production area. The observation of environmental behavior is limited, in the past, to the changes of land-cover on the rural properties of landowners, i.e. deforestation.[17] In the present time, it is however possible to ask about the agricultural practices implemented by producers, which broadens the conceptualization of environmental behavior from simply deforestation to agricultural practices.

The analyses done at the regional level (either a sub-part of Mato Grosso or at the state-level itself) have not allowed a discussion of why some landowners have preserved more native vegetation than others. Although these differences have been pointed out, they are merely attributed variation in property size (Godar et al. 2014b). The average deforestation estimates

[17] In this dissertation, I understand deforestation broadly as the replacement of native vegetation by modern agricultural activities. I therefore exclude prior use of this vegetation by indigenous people or other types of use like selective logging of noble tree species, or rubber plantations. Using native vegetation instead of forests allows me to encompass a larger set of vegetation types subject to conversion by agricultural activities such as savannas, grasslands, etc. It has the other advantage of matching with the vocabulary used by environmental laws regulating land-use in Brazil. Rules of environmental conservation cover more vegetation types than forests and include a range of diverse vegetation known to be there prior to the creation of a rural property, i.e. native vegetation.

presented in such studies indeed hide considerable variation in the data, resulting in inferences about the behavior of producers that are highly influenced by the level at which researchers look at the data (called by some authors "level-dependent deforestation") (Brondizio and Moran 2012). Explaining this variation is therefore key since it may shed light on the factors determining why agents respond differently to similar stimuli provided by economic or institutional conditions.

The analysis of large-scale soybean producers' transition from high- to low-deforestation and their changing agricultural practices thus requires broadening the scope of conditions and processes influencing behavior. In this dissertation, I extend the scope of inquiry by examining the conditions (Chapters 1, 2 and 3) in which large scale producers have cleared their property (Chapter 4), and how their production strategies (Chapter 5) and environmental values and perceptions have influenced their agricultural practices (Chapter 6).

The first objective of this dissertation is to examine how producer behavior was affected by the specific institutional context in which they colonized Mato Grosso, and how the characteristics of these colonizers help explain the variability of environmental behavior at the frontier. My first research question is thus: (1) **To what extent did macro-scale and micro-scale conditions affect the land-use decision-making and the environmental behavior of this group of producers?** After a broad description of the political and economic structures (i.e. institutions) in which producers have arrived in Mato Grosso, I describe the commonalities and differences existing within the group farmers who emigrated from Southern Brazil. I argue that the specific project shared by these farmers to develop agriculture in Mato Grosso mattered, since similar groups of farmers who headed for other areas of the country did not end up reproducing the same production

model. An important assumption of this work is that it is the interaction of producers' characteristics and cultural identity with the broader set of biophysical characteristics, technological conditions, and institutional structures that resulted in the emergence of soybean production areas. This question will be explored in Chapters 1, 2, and 3.

If this particular interaction is indeed responsible for the transformation of Mato Grosso's frontier into leading soybean producing areas, then one would expect to see differences in environmental behavior *produced* by such interaction. My second question is therefore: **(2) What were the property-level land clearing trajectories (patterns) of producers (and did they respond to policy changes)?** I show that there are important commonalities and differences in the land clearing patterns across individuals and across municipalities which cannot be explained by environmental policies or market conditions alone. This question is explained in Chapter 4.

At least part of the environmental behavior of soybean producers of Mato Grosso has therefore been influenced by something other than policies or markets. I argue that current approaches to understanding this behavioral transition crucially miss insights about the *processes* which made this transition possible. My third question is therefore: **(3) Which changes in production strategies help explain the changes in land use and environmental behavior?** The stagnation of land clearing in soybean producing areas of Mato Grosso from the mid-2000s was made possible by production strategies that fundamentally permitted producers to remain profitable with the same cultivated area (as opposed to extending over more land). I therefore explain in Chapter 5 how the transition toward land clearing stagnation was in fact underpinned by underlying and long-term production system changes.

Having explained how soybean producers can remain profitable in an era where expanding over new land is highly restricted by environmental policies and market-based initiatives, it is necessary to characterize the variability in environmental behavior as embodied in agricultural practices. My fourth and last question thus is: **(4) How do environmental perceptions and values help explain today's land-use patterns and adoption of good agricultural practices (GAPs) by producers?** I demonstrate the role that the self-defined identity of producers, composed of a set of environmental values and perceptions, determine the type of agricultural and conservation practices they adopt today. Chapter 6 examines how these elements represent a significant influence of soybean producers' behavior and their very identity as producers. **Table 0.1** provides a summary of the chapter-specific research questions.

Chapters	**Questions**	**Type**
Ch. 1 Colonization history	How did the location and particular colonization conditions (i.e. project type) influence land-use type?	Conditions (macro)
Ch. 2 Soybean farmers history	How do the characteristics of farmers, as individuals and as a group, help explain land-use type?	Conditions (micro - meso)
Ch. 3 Environmental policies	Do environmental policies (in light of market conditions) explain the evolution of land clearing/use?	Conditions (institutional)
Ch. 4 Clearing history	What were the property-level clearing trajectories?	Patterns
Ch. 5 Production strategies	Which changes in production strategies help explain the changes in land use and environmental behavior?	Processes
Ch. 6 Values, Perceptions and GAPs	How do environmental values and perceptions explain today current land-use patterns and adoption of GAPs? How does the evolution of values explain the evolution of GAPs?	Patterns (and conditions)

Table 0.1. List of chapters, corresponding research questions, and type of evidence

4. CONCEPTUAL FRAMEWORK FOR THE DISSERTATION.

Broadening the scope of analysis of the environmental behavior of large-scale soybean producers requires adopting a conceptual framework that can incorporate the wealth of variables at play in this situation. It is especially important to provide this thick description to understand how the individual-level variables (i.e. characteristics) of soybean producers interacted with the set of conditions present in Mato Grosso to produce environmental outcomes differing in time and space. Rather than "reducing" the influence of each variable to a precise effect, I set out to "distinguish" the role played by each of these variables and describe their interaction with one another (Morin 2015). In the following sections, I explain my approach to institutional analysis, policy analysis and the study of environmental values.

4.1. AN INSTITUTIONAL ANALYSIS FRAMEWORK TO ORGANIZE THE INQUIRY

In order to comprehend how the relationships between economic, social, ecological, and institutional variables can lead to a variety of behavioral outcomes, social scientists have traditionally relied on frameworks, which provide a way to combine different theories, methods and variables to explain the evolution of institutional arrangements. According to Ostrom, the purpose of frameworks is to "identify the elements and general relationships among these elements that one needs to consider for institutional analysis and … organize diagnostic and prescriptive inquiry" (Ostrom 2011: 8). Such frameworks are interdisciplinary in nature and are needed to improve comparability across socio-ecological systems case studies, ensure an exhaustive review of all key variables influencing a particular outcome, and provide a necessary basis for establishing strong causal relationships between political, economic, institutional variables and ecological outcomes (Ostrom 2011; Robbins, Chhatre, and Karanth 2015). Two major frameworks, both developed by Elinor Ostrom and colleagues, have influenced the study of socio-ecological

systems: the Institutional Analysis and Development framework (IAD) and the Socio-Ecological Systems framework (SES). Recently, researchers in this line of inquiry have developed a combined IAD-SES framework (CIS) to address the shortcomings of both approaches (Cole et al. 2019).

The IAD framework (**See Figure 0.2**) was developed to explain how actors with diverse interests interact strategically with one another under the influence of three key factors: the actors' social environment (i.e. the communities and context in which they live), the type of natural resource or goods at stake, and the 'rules-in-use'[18] shaping collective and individual action (Cole et al. 2019). It provides a useful way to analyze how a broad set of variables (physical, social, economic, and institutional) shape how actors make individual and collective decisions that will in turn have an impact on collective-choice, policy or constitutional change, depending on the level at which such interactions occur.[19] The framework examines such interactions within an "action situation"[20] that corresponds to a defined set of actors, processes, and fixed period in time. When analyzing multiple successive time periods, outcomes of past phases will affect the conditions that will prevail for the next phase (feedback mechanism), and each action situation can also influence or be influenced by other adjacent action situations occurring at similar or different times (McGinnis 2011). For example, the characteristics of agricultural development in one region in the 1950s might affect, at least partly, how agricultural expansion works in another region in the 1960s.

[18] As explained by Cole et al., 'rules-in-use' "incorporate explicit legal rules as well as more informal norms and shared understandings" (Cole et al., forthcoming, p.2)

[19] Ostrom (2005) distinguishes between three level of interactions or "action situations": (1) operational choice level (how actors adapt their behavior in response to policies and rules); (2) collective-choice level (how actors make collective choices about the rules that will structure their behavior at the operational level); and (3) constitutional choice level (how actors define who and how collective choices will be made)

[20] As defined by Ostrom (2011: 11): "Action situations are the social spaces where individuals interact, exchange goods and services, solve problems, dominate one another, or fight (among the many things that individuals do in action situations)"

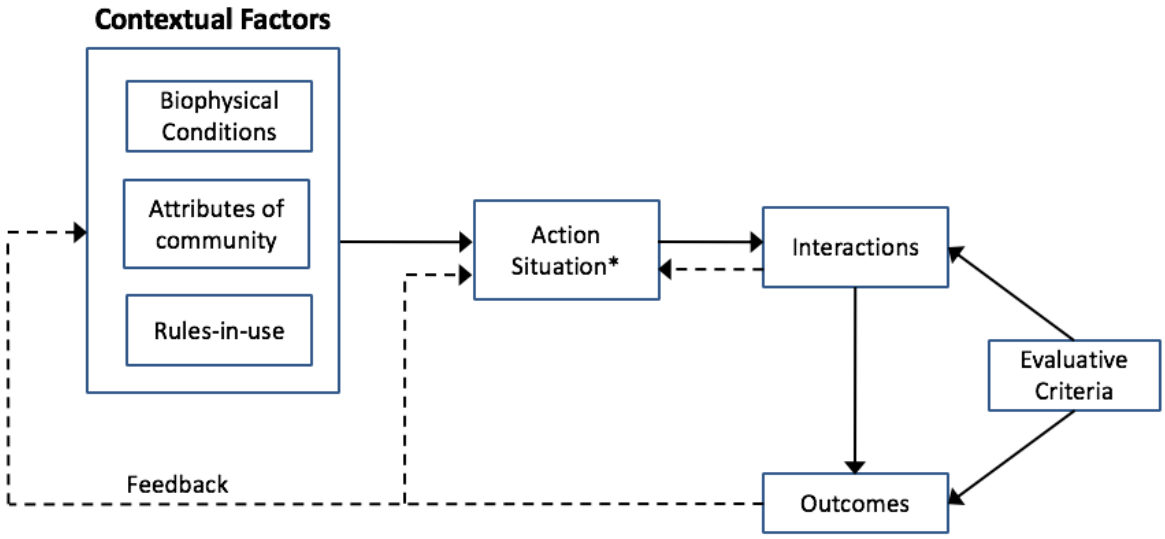


Figure 0.2. The IAD framework and its basic components (Adapted by Cole et al. 2019, based on Ostrom 2010: 646).

The SES framework was developed by the same community of researchers in response to criticism that the IAD did not sufficiently embrace the complexity of socio-ecological systems and the key influence of ecological variables (Epstein et al. 2013; Ostrom 2007; Ostrom and Cox 2010). The main innovation of the SES framework was refining the analysis of IAD's biophysical conditions box by distinguishing between resource systems (RS) and resource units (RU), allowing the analyst to choose from an exhaustive menu of variables of potential relevance to explain interactions. This innovation had however the unintended effect of displacing attention from action situations to a complex menu of variables, making the analysis more static than dynamic (Cole et al., 2019).

The combined IAD-SES framework (CIS) combines the strengths and avoids the pitfalls of both frameworks by incorporating the categories and list of variables of the SES framework directly into the IAD framework structure (**See Figure 0.3**). First, this allows for a finer interpretation of the interplay of physical, social and institutional variables but keeps a central focus on the main processes and interactions studied. Second, the central "action situation" box of the IAD has been

replaced by a box potentially including all action situations relevant to a given case. Finally, the feedback loop of the IAD whereby current patterns of interaction influence the pre-existing conditions of future interactions is now logically a feed-forward arrow: outcomes of a past action situations directly affect the conditions of the action situations under study.

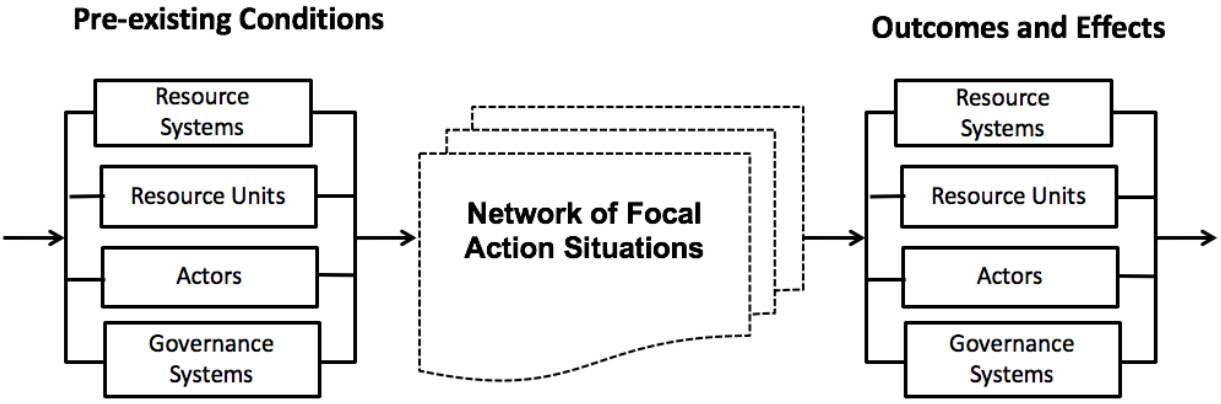


Figure 0.3. Generic representation of the CIS framework (Cole et al., 2019)

If the CIS is not a theory or a body of theories per se, it is a useful way to map out all the key variables and processes at play in a given situation (e.g. the management of a common-pool resource such as fisheries), and thereby increases the comparability of the impact of rules and institutions across diverse case studies. By adopting an exhaustive set of categories to describe variables relevant to socio- ecological systems, it also allows for the formulation of new hypotheses and may potentially lay the groundwork for causal inference between remotely connected variables and local outcomes in commodity production areas of various kinds (Robbins, Chhatre, and Karanth 2015), as the literature on telecoupling reveal (Liu et al. 2013). It can help case studies to look beyond just local conditions and explore, for instance, the relationship between a growing protein demand in China and local outcomes like soybean cultivation in Brazil (Silva et al. 2017).

4.2. ENVIRONMENTAL BEHAVIOR: THE ROLE OF POLICY, MARKET CONDITIONS, AND ENVIRONMENTAL VALUES

The theoretical challenge associated with this dissertation project is to explain how producer behavior evolves as a result of multiple variables interacting together. I adopt a broad analytical perspective which can provide a conceptual basis explaining environmental behavior in its different declinations (from deforestation to particular agricultural practices).

4.2.1. Understanding land-use decisions as complex interactions, relying on the CIS framework

As stated above, land-use decisions (and their environmental implications) are the result of complex interactions between a universe of remote, contextual variables and individual-level decisions to produce land-use outcomes. Unfortunately, the relevance of such variables for explaining producer behavior tend to be determined by the level at which the analysis is carried out. For instance, micro-level studies (i.e. producer-level) focus on single individuals and interpret behavior as the expression of individual traits in reaction to a set of economic and institutional conditions. On the other hand, macro-level studies explain the sum of thousands (or more) individual decisions as a monolithic pattern (i.e. one collective decision) resulting from great structural forces (e.g. market price variations, policies, etc.). The latter approach has the disadvantage of looking at average patterns and disregarding the (often extreme) variability of individual behaviors (Edwards-Jones 2006a). Both approaches bring different and complementary information on the drivers of land-use change, but simply combining them would only imperfectly address fundamental questions of the social sciences: to what extent do land-use decisions and outcomes reflect the agency of individual landowners or pertain to broader socio-ecological processes of which farmers are only mere "executants"? To address this, I outline below a

conceptual model of land-use decision-making that takes into account the complexity of both individual choices and the decision-making environment, relying on the terminology of the CIS framework (to the extent possible).

The agricultural land-use decisions of producers (i.e. agents) are primarily bounded by "enabling conditions" that are a mix of local and general conditions making some types of land-use possible in a given place. Biophysical conditions determine whether a certain type of agricultural activity is suitable to soil, climate, topography and the ecological characteristics of a specific region. Among general conditions, one can find the type/level of technology available (e.g. type or variety of crops, inputs, mechanization etc.), since technology can help overcome some of the biophysical limitations associated to a given place. For instance, agriculture expanded in the Cerrado and Amazon areas of Brazil only after important technological breakthroughs helped reduce the natural acidity of soils in these areas and brought about new crop varieties adapted to the climatic characteristics of these biomes (e.g. photoperiod). Technology also determines in great part the type of agriculture that predominates the area by determining production costs. For instance, the rationale of soybean agriculture is to rely heavily on machinery, therefore it needs areas with no or low declivity for the machines to perform adequately. Broader technological conditions such as infrastructure are also important as they are a necessary (but not sufficient) condition to the profitability of agricultural activities. Crop or commodity prices have an ambiguous role because, if a minimum price is necessary, once this threshold is passed, any price fluctuations do not fundamentally re-question the cultivation of the crop.[21] In other terms, enabling conditions define

[21] Angelsen and Kaimovitz (2001) give the example of how soybean cultivation expanded in Southern Brazil despite downward price fluctuations. Since profitability is ultimately defined by the difference between production value and costs, the fact that crop prices decrease is not necessarily a "problem." It may simply push producers to adopt different

the total space technically available (*real* land scarcity) for agricultural activities in a given place. All such conditions can be found in the [Pre-existing conditions: resource systems, resource units] boxes of the CIS framework (**See Figure 0.2**).

Structuring conditions are further composed of institutions, the presence or absence of which underpin what land-use can or cannot be done, and its geographical extent. Both formal (laws, policies and plans) and informal (social norms, customs, etc.) institutions make up the "working rules" (Cole 2017) that define the geographical scope within which agricultural land-use is permitted. In this respect, colonization programs and plans (generally accompanied by infrastructures and communication networks) based on private property rights allocation can promote agricultural expansion into areas not previously subject to intense economic use. Market conditions (crop price, production costs, etc.) then influence the extent of land cultivated and the type of crop with significant fluctuation. Land-use planning and environmental policies act as countervailing forces and may delineate the contours of that expansion by constraining agricultural activities to spatially delineated areas. More often than not, this happens through the creation of areas with a specific protected status (e.g. protected areas, conservation areas, indigenous lands) onto which private agricultural activities cannot be carried out legally. Environmental policies may also impose land-use restrictions on private land. Institutions result in territorial constriction in the sense that they artificially constrain agricultural activities within an institutionally-defined space (Thaler 2017). In short, institutions create *artificial* land scarcity (in addition of *real* land scarcity) defining the total space "artificially" available for agricultural activities. All such conditions can be found in the [Governance Systems] box of the CIS framework (**See Figure 0.2**).

production models that help them lower costs and recreating profit margins, and this may involve expanding cultivated area.

Once these two sets of conditions ("enabling" and institutional) are established, the "what do people do with these conditions?" question remains. These conditions indeed help describe why crop cultivation takes place in one place and not in another, but they do not explain why certain types of crops are cultivated rather than others (in areas with similar soil types) (Edwards-Jones 2006b), nor do they determine why some individuals clear more land for agriculture than others. The individual characteristics of farmers that may be relevant to land-use decision-making are numerous (Burton 2004b, 2004a, 2014). The most common characteristics are education, technical training, wealth, capital and funding, tenure, information, number of farm employees, etc. However, additional social-psychological variables help define producer strategies and must be included, such as the cultural identity, values, perceptions and attitudes vis-à-vis agricultural practices or institutions. One must also account for commonalities existing between farmers in the same region, since there may be some variables influencing decision-making relevant at the group-level. These "attributes of the community" or group characteristics describe the common cultural origin of producers, their shared vision of agricultural production, their patterns of cooperation and competition, family structure (as relevant to production operations), and other characteristics that may have an impact on land-use decisions but do not directly pertain to individual traits. All such conditions can be found in the [Actors] box of the CIS framework (**See Figure 0.2**).

There are series of adjacent action situations going on at the same time (McGinnis 2011). An example of such situations can be the land-use decisions and the conservation decisions made by producers. These decisions are interlinked but yet do not depend exactly on the same factors, although one (i.e. land-use) may heavily determine the other (i.e. conservation). On the contrary,

one may point out that conservation decisions, partly imposed by law, do put a limit on land-use decisions (provided producers want to comply with the law). Thus, in this conceptual approach, environmental policies and market conditions play a significant role depending on the particular action situation, i.e. the particular decision being made by individual actors. These factors however insufficiently explain the outcome since the CIS framework includes several additional influencing decisions. Such differences in other factors than policies or market conditions may explain why some type of land-use (and conservation) done in one place is different from another place. For instance, agricultural producers in one place might make decisions that are consistent with policies and market conditions because their environmental values and perceptions are in line with them. In other places, producers with a different mentality may choose a very different behavioral path. Finally, this framework is grounded in time: What happens at one period of time will affect the next period. This means that it assumes that the actions of actors done in the past will inform the situation in the present, since actors learn from their past behavior and its outcomes.

4.2.2. The evolution of environmental behavior through practice and environmental values

Over the course of their lifetime in a particular place, agricultural producers accumulate experience about agricultural practices as well as learn from the biophysical, market, and institutional conditions in which they operate. Among the variety of information parameters influencing their decision-making process about land-use, environmental values hold particular importance in guiding their actions. It is however important to clarify first why socio-economic parameters may not be the only relevant factor to explain behavior.

Traditional economic models of decision-making tend to over-emphasize the role of financial incentives in decision-making because of their direct contribution to a person's utility (Edwards-Jones 2006). Not all decisions are equal, hence these approaches tend to better explain decisions in which the monetary component is relatively more important than others, such as the decision of planting a crop. Conservation decisions, on the other hand, may include financial components (e.g. costs of planting trees or grasses) but non-financial parameters may likely influence them more than in production decisions. In addition, non-financial parameters also contribute to utility levels and, as one person's wealth and preference structure changes, may take on more importance than financial considerations. Because the focus here is on a group of farmers who are wealthier than others in the same area, I expect the economics-based approach to be less relevant to study the adoption of a variety of agricultural and conservation practices, as I hypothesize that their decisions are less likely to be determined by financial parameters.

Under the influence of social and cognitive psychology, broader behavioral approaches have sought to integrate economics-based thinking with additional non-economic elements such as farm characteristics, farmer attitudes and values, and so forth (Burton 2004b). Two approaches have been particularly influential to the study of farmer decision-making: The Theory of Planned Behavior (TPB), now labeled Reasoned Action Approach (RAA) (Fishbein and Ajzen 2010), and the Values-Beliefs-Norms (VBN) theory (Stern 2000). The TPB helped explain environmentally significant behavior (e.g. adoption of GAPs) through the role of attitudes, social norms and behavioral perceptions. In this model, various beliefs influence these factors and translate into behavioral intention, which ultimately results in behavior unless some particular context prevents this from happening. Although many adoption studies started using the TPB as a way to explain

both intended behavior and actual behavior (Baumgart-Getz, Prokopy, and Floress 2012; van Dijk et al. 2016), some authors remark that the overwhelming focus on attitudes has led to limited insights (Burton 2004b; Edwards-Jones 2006b). Attitudes indeed received the lion's share of attention while social norms and perceptions of behavioral control have been largely overlooked by most studies. The focus on attitudes has equally obscured the rise of alternative explanations to environmentally significant behavior centered on other constructs such as farmer's self-identity (Burton 2004a). The VBN theory has taken a different approach than the TPB by re-centering the analysis around the core role of values and how they influence individual attitudes, assessments, and behavior in a cascading way (**See Figure 0.4**). In the following paragraphs I outline further how this approach works and why I believe it is most relevant for studying farmers of Mato Grosso.

The concept of values differs from several others in social psychology, namely *attitudes*, *trait*, *norms*, *needs*, *roles*, and *preferences* (for a complete distinction of these concepts, please see Dietz et al. 2005). In particular, operationalizing the values concept for this study requires distinguishing it clearly from *attitudes* and *norms*, the other concepts not being directly relevant here. Values are "(a) concepts or beliefs, (b) about desirable end states or behaviors, (c) that transcend specific situations, (d) guide selection or evaluation of behavior and events, and (e) are ordered by relative importance" (Schwartz and Bilsky 1987: 551, as cited by Dietz 2005: 346).[22] Valuing a particular aspect of the landscape (e.g. water) is different than the *attitude* toward some specific proposition about it (e.g. to be in favor or against the use of water for irrigation purposes). The difference lies

[22] Another classic definition of human values is the one provided by Rokeach: Human values: "transcend specific objects and specific situations: values have to do with modes of conduct and end-states of existence. More formally, to say that a person 'has a value' is to say that he has an enduring belief that a particular mode of conduct or that a particular end-state of existence is personally and socially preferable to alternative modes of conduct or end-states of existence" (Rokeach 1968: 550)

here between the general (*values*) and the specific (*attitudes*), the latter being almost always "positive or negative evaluations of something quite specific" (Dietz, Fitzgerald, and Shwom 2005: 346). A *norm* is slightly different too in that it is a statement of what a person thinks people 'ought' to do. Following this example, one person might think that "people ought to use water for irrigation and agricultural development" or, on the contrary, that "people should never be using water for any agricultural purpose to avoid threatening the resource."

Other constructs close to values are *beliefs* and *worldviews*. For Dietz et al. (2005), *beliefs* are "understanding[s] about the state of the world, they are facts as an individual perceives them" while *worldviews* are "generalized beliefs" (Dietz 2005: 346). For instance, many farmers in Mato Grosso have diverging *beliefs* regarding the role of forest in the regulation of rainfall patterns. Some believe that forests have grown here precisely as a result from regional rainfall patterns, hence cutting down trees should have no impact on precipitation rates, while some other believe that cutting down trees does, in fact, reduce rainfall in a particular area. A *worldview* example of the former group would be the idea that farming activities rarely have any impact at all on the environment *in general*.

The *values-beliefs-norms* (VBN) theory has offered a framework for linking values to actual environmental behavior and has demonstrated its relevance in many instances (Fransson and Gärling 1999; Stern 2000; Guagnano, Stern, and Dietz 1995). According to this theory, values ultimately determine behavior through a chain causation system that goes through different levels affecting a person's beliefs, perceptions and norms (see Figure 2.1.). As summarized by Dietz: "The theory suggests that values influence our worldview about the environment (general beliefs),

which in turn influences our beliefs about the consequences of environmental change on things we value, which in turn influence our perceptions of our ability to reduce threats to things we value" (Dietz, Fitzgerald, and Shwom 2005: 356).

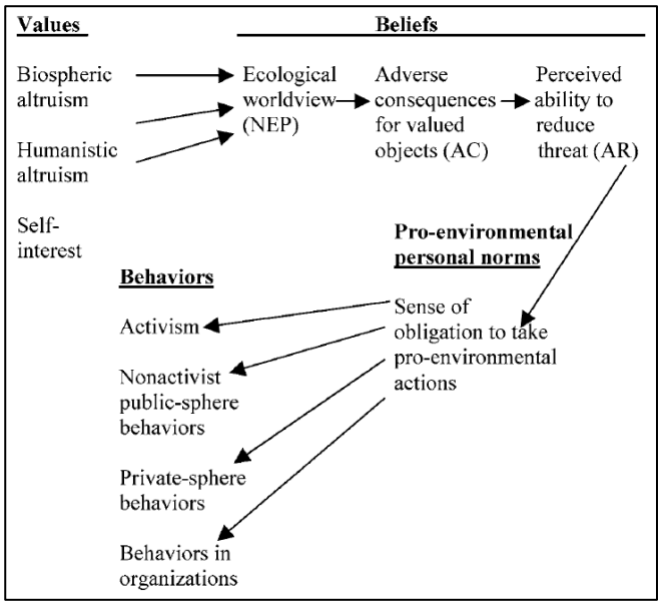


Figure 0.4. Values-Beliefs-Norms (VBN) theory, as drawn by Dietz et al. 2005

However, there are various meanings to environmental values, and not all apply the same way. In the present case (the VBN theory), the meaning of value "resides within individuals as the structure of their priorities" rather than referring "to the importance of a particular environmental object" (Tadaki, Sinner, and Chan 2017: 7). This study therefore departs significantly from the literature on environmental values as used in the VBN theory by referring to farmer's values as the *importance they attach to particular environmental objects* such as forests, water, and their related ecosystem services such as (local and global) climate regulation.

It is one of the main assumptions of this dissertation that environmental values, in the sense of particular environmental objects (1) guide producers' behavior; (2) evolve along with their agricultural practices. Agricultural practices and environmental values are "co-constructed" in the

sense that they both influence and are influenced by each other (Hards 2011). Agricultural practices lay the seeds for changes in environmental values, which in turn influence the adoption of new practices. Since it is not the objective of this study to *prove* that environmental values guide behavior in general, I therefore rely on the wealth of evidence already provided by the social-psychology literature on environmental values outlined above.

5. A RESEARCH DESIGN TO ANALYZE THE AMAZON-CERRADO TRANSITION AREA OF MATO GROSSO

5.1. GEOGRAPHICAL DESCRIPTION OF THE STUDY AREA

Mato Grosso is one of 9 states that are part of the Legal Amazon and overlaps with three distinct biomes: the Amazon forest, the Cerrado, and the Pantanal. Soybean agriculture started by developing in the Southeastern part of the state in the late 1970s and gradually occupied 5 different regions with different biophysical contexts (Arvor et al. 2012). In this dissertation, I examine particularly the two most important production regions of the state. Located north of Cuiabá (the state capital), the regions of the BR-163 highway[23] and the Chapada dos Parecis are part of the northern Mato Grosso meso-region (*mesoregião),* the largest of the 5 meso-regions composing the state of Mato Grosso. The northern meso-region marks the division of Mato Grosso between the Amazon river basin, the Platina river basin (south of the state, flowing to the Paraguai river), and the Tocantins river basin (east of the state, where the Araguaia river flows). The two areas of study in this dissertation are located in two micro-regions (*microregião*) within the northern meso-

[23] The BR-163 is not a region *per se*, but is an expression commonly referred to in the literature to describe all the regions of Northern Mato Grosso following the path of the BR-163 highway to Pará. It starts south with the municipalities of Nova Mutum and goes up to the extreme north of the state, Guarantã do Norte. The road then keeps going from south to north in the state of Pará until the town of Santarém. When using "BR-163" in this dissertation, I will refer to the region of the Alto Teles Pires and Sinop, comprising Nova Mutum, Lucas do Rio Verde, Sorriso, and Sinop, and municipalities bordering them, unless otherwise indicated.

region. One is the plateau of the Chapada dos Parecis (altitude: 250-750 meters) and is considered to be the major *"divisor das águas"* (river-basin dividing line) between those three river basins. The other is the Alto Teles Pires (altitude: 250-500 meters) to which I added the Sinop micro-region[24] (**See Figure 0.5**).

[24] When writing about the Alto Teles Pires region, I will therefore always implicitly include the municipality of Sinop, unless otherwise stated.

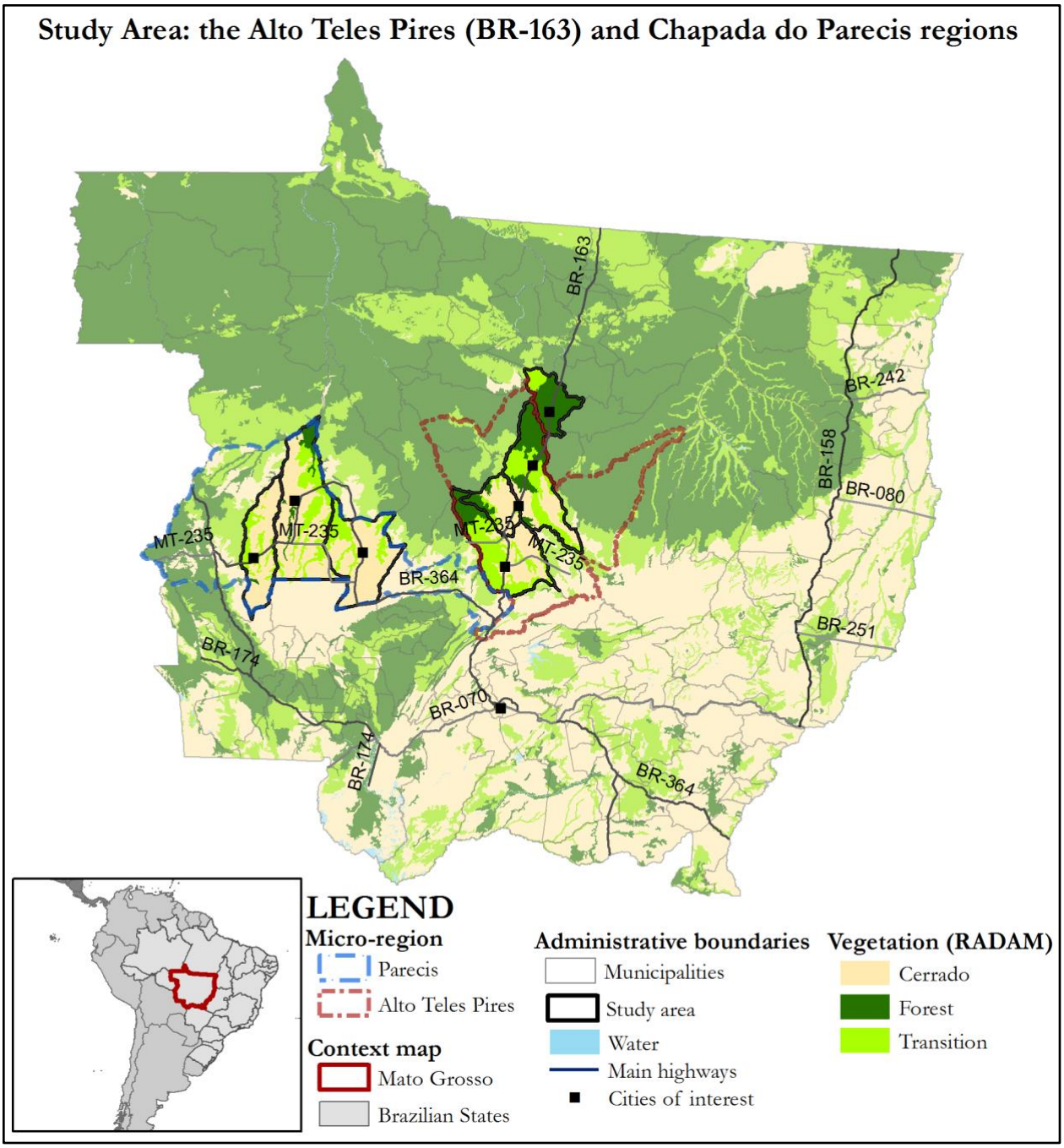


Figure 0.5. Map of the study area outlining the municipal boundaries and microregion of the Alto Teles Pires (BR-163) and the Chapada dos Parecis boundaries. **Methodology:** See Annex for methodological details

Importantly, these two regions are large plateaus situated in a transition area between the Cerrado and the Amazon ecological biomes. As such, the vegetation in this area is a complex "mosaic" of grasslands, bushes, woodlands and semi-deciduous forests, typical of the Cerrado (Ackerly et al. 1989). As one heads farther north of the study area and beyond, denser tropical rainforests of the

Amazon dominate the landscape. As **Figure 0.6** shows, the vegetation present in the Cerrado is composed of three main classes of vegetation formations: (1) forest formations; (2) savanna formations (commonly referred to as Cerrado); and, (3) "campestre" formations (i.e. field vegetation) (Ribeiro and Walter 1998). The Cerrado *sensu lato*[25] comprises three broad subtypes of vegetation: (1) *campo Cerrado* (grasses) ; (2) *Cerrado sensu stricto* (savanna); and, (3) *cerradão* (woodland) (Jepson 2005).

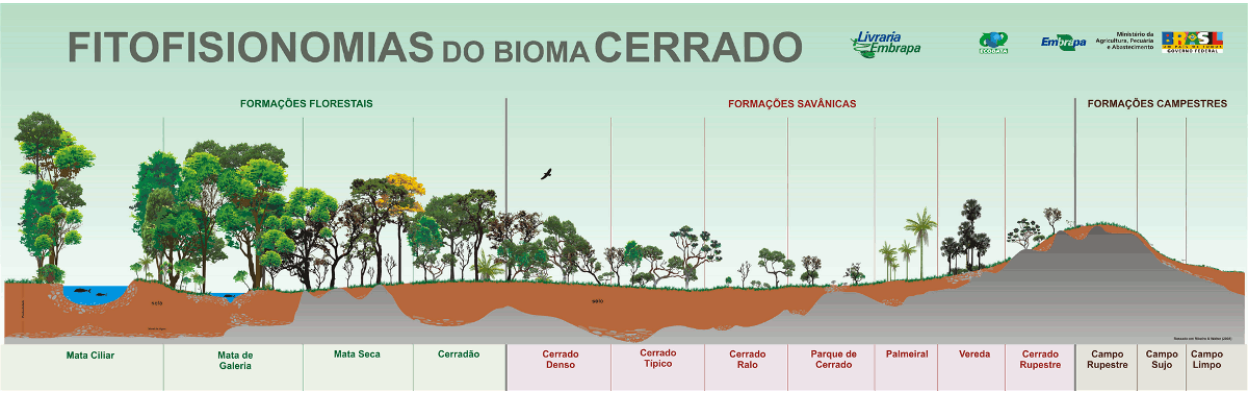


Figure 0.6. Vegetation formations of the Cerrado biome. Source: EMBRAPA

The Cerrado thus includes important areas of seasonally dry tropical forests and riparian forests "linking" this ecological biome to the Amazon biome in areas classified as "contact" or "transition" areas ("areas de contato" or "areas de transição" in Portuguese) (Fearnside and Ferraz 1995; Fearnside and Barbosa 2003). Over long periods of time when climate varies significantly, the Amazon forests actually go back and forth into the Cerrado biome, moving along the rivers (for instance, along the denser forest cover along rivers) in what researchers have qualified as a "hyperdynamic" area (Marimon et al. 2014; Passos et al. 2018). As a result, many patches of forests may appear in the savanna areas of the Cerrado, and large areas of forests may be located outside what is delineated by the official Amazon biome boundaries (Marques et al. 2019).

[25] In the broad sense

Numerous rivers have their origin in this extremely water-rich region. Water springs are ubiquitous in the area, and the state of Mato Grosso itself is considered to be the *caixa d'água*, the "water tank," of Brazil.[26] The Teles Pires river (which gives its name to the micro-region) starts in Mato Grosso and flows into the Tapajós river, which itself flows into the Amazon river. Water in the area represents both an important "safety net" for agriculture in case of climate change and a potential key transport infrastructure for exporting crops from ports of the Amazon river.

The Amazon-Cerrado transition area is characterized by well-defined rainy and dry seasons, and receives abundant rain ranging from 1,500 to 2,400 millimeters (mm), which makes tropical agriculture both easier and more challenging (i.e. need for adapted crop varieties) (Arvor 2009: 306). The region also consists of flat lands until declivity increases in a light slope when approaching rivers, which amounts to an ideal topography for mechanized agriculture. Despite the assets in the area, soil fertility is considered low. The soils of the Cerrado are characterized by high concentrations of aluminum (and are thus highly acidic), and lack essential nutrients such as phosphorous (Wilkinson and Sorj 1992; Spehar 1995).

5.2. Sample selection and units of analysis: 104 Producers, 7 municipalities, and 2 biomes

Focusing on areas of historical soybean production in the Amazon-Cerrado transition areas of Mato Grosso, the goal of the sample selection strategy is to maximize the variability of the variables of interest:

[26] http://www.mt.gov.br/geografia

(1) *Maximizing the variability of environmental policy enforcement keeping homogeneity in land-use (i.e. soybean agriculture)*. Given that much of the environmental policy enforcement relied on satellite-based monitoring of forest cover, I selected a group of municipalities that represent a gradient of vegetation cover from Cerrado-dominated areas to forest-dominated areas. This difference in degree of forest presence helps capture different levels of policy pressure over the study area, which will help determine whether the variability in landowners' environmental behavior can be linked to a policy response.[27]

(2) *Maximizing the variability within the group of large-scale landowners* in order to best analyze the variability in land-use and environmental behavior within that group. I do not attempt to compare all soybean farmers. Instead, I am looking at a specific sub-group whose environmental behavior is less likely to be influenced by socio-economic factors (since they are already prosperous) and more likely to be influenced by variation in environmental values.

The research takes place in the two consolidated frontiers of Mato Grosso (BR-163 highway region and Chapada dos Parecis region) representing the lion's share of soybean production in the state. The first area is located along the BR-163 highway connecting Cuiabá to Santarém, and comprises the municipalities of Nova Mutum, Lucas do Rio Verde, Sorriso, and Sinop. The second location is in the Chapada dos Parecis, and includes the municipalities of Campo Novo do Parecis, Sapezal, and Campos de Júlio (**See Figure 0.7**). Together these 7 municipalities represented 26.5%

[27] However "enthusiastic" as one can be about such a research design, I must caution that this implicitly relies on the assumption that environmental agencies would enforce the law "uniformly" across the Amazon, with no budget restrictions, as long as any hectare of forest is cleared and reported by the satellite-based monitoring system. Unfortunately, nothing would be farther from the truth, as environmental agencies have budget and political constraints that greatly affect their scope of action.

of Mato Grosso's soybean production in 2016 (6.9 million tons of soybeans). Municipalities provide a coherent political-administrative boundary to the study of soybean agriculture and deforestation since most of these municipalities were created following the colonization of the frontier.[28]

[28] Municipalities are the smallest spatial units of Brazil's political-administrative division, with the exception of districts (which are sub-divisions of municipalities). Their size can vary greatly depending on the state, and whether the area is urban or rural. These territories are headed by a *prefeito* (the equivalent of a mayor or county administrator in the United States). At the time of the separation of Mato Grosso into two states (i.e. in 1977 this state was split between "Mato Grosso do Sul," the southern part, and "Mato Grosso", the northern part) only counted with a few municipalities that covered a very large part of the states (For instance, the municipality of Chapada dos Guimarães or Nobres). As the colonization of the frontier progressed, residents of these new areas petitioned for the delineation of their own municipalities, which would give them some fiscal autonomy and public service missions. Today, Mato Grosso has 141 municipalities.

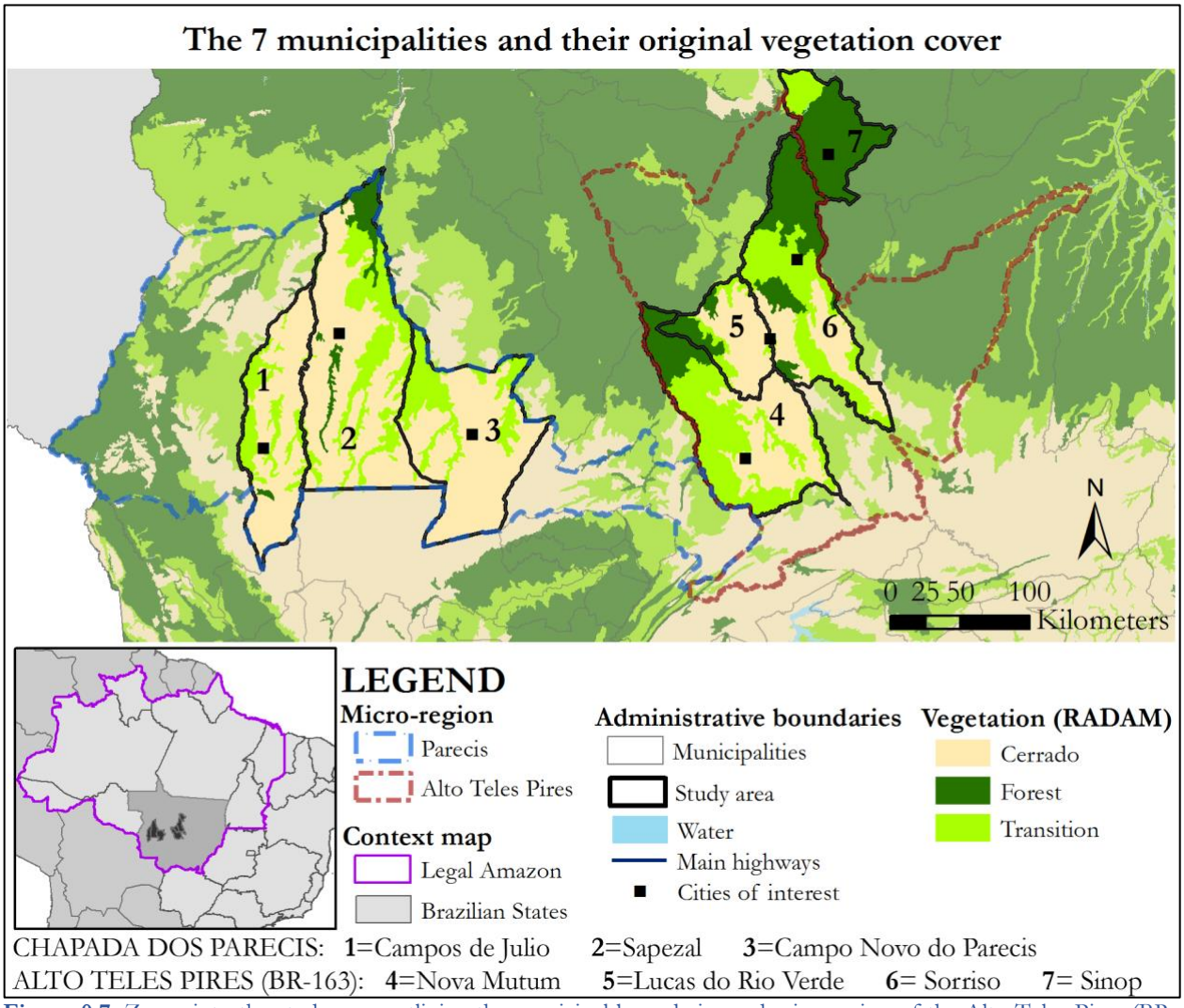


Figure 0.7. Zoom into the study area outlining the municipal boundaries and microregion of the Alto Teles Pires (BR-163) and the Chapada dos Parecis boundaries.

This group of municipalities is particularly interesting because they transitioned from high to low deforestation at the very moment soybean production exploded, following the pattern of a "great acceleration." As one can see on **Figure 0.8,** the increase in agricultural production occurred during a period when deforestation rates were high throughout the 1995-2005 period but much lower during the 2005-2015 period, demonstrating that part of the production expansion happened through agricultural intensification and expansion over former pastures more than expansion over forests (i.e.) (Morton, DeFries, Shimabukuro, Anderson, Arai, Espirito-Santo, et al. 2006; Arvor

et al. 2012). The development of double-cropping system (i.e. allowing a second harvest within the same calendar year) caused similar production volume explosions for maize and cotton starting in the 2000s although not in the same proportion in each study area. It seems that maize has been the privileged crop for a second harvest in the BR-163 region while the larger-scale farms of the Chapada dos Parecis have embraced more capitalistic production systems by adopting cotton. Despite such a transition, 20%-45% of the native vegetation cover is still preserved in the municipalities of the study area

It is thus particularly relevant to analyze this group of municipalities leading soybean production in the area since it offers a window into the mechanisms and real implications of sustainable intensification (Pretty 2018; Rockström et al. 2017). At stake is a debate about whether the study area represents some "ideal" model of development for the Amazon. This model has undoubtedly brought economic and social development while also casting concerns about inequality and environmental damages (Rachael D. Garrett and Rausch 2015; Martinelli et al. 2017; Philip M. Fearnside 2001).

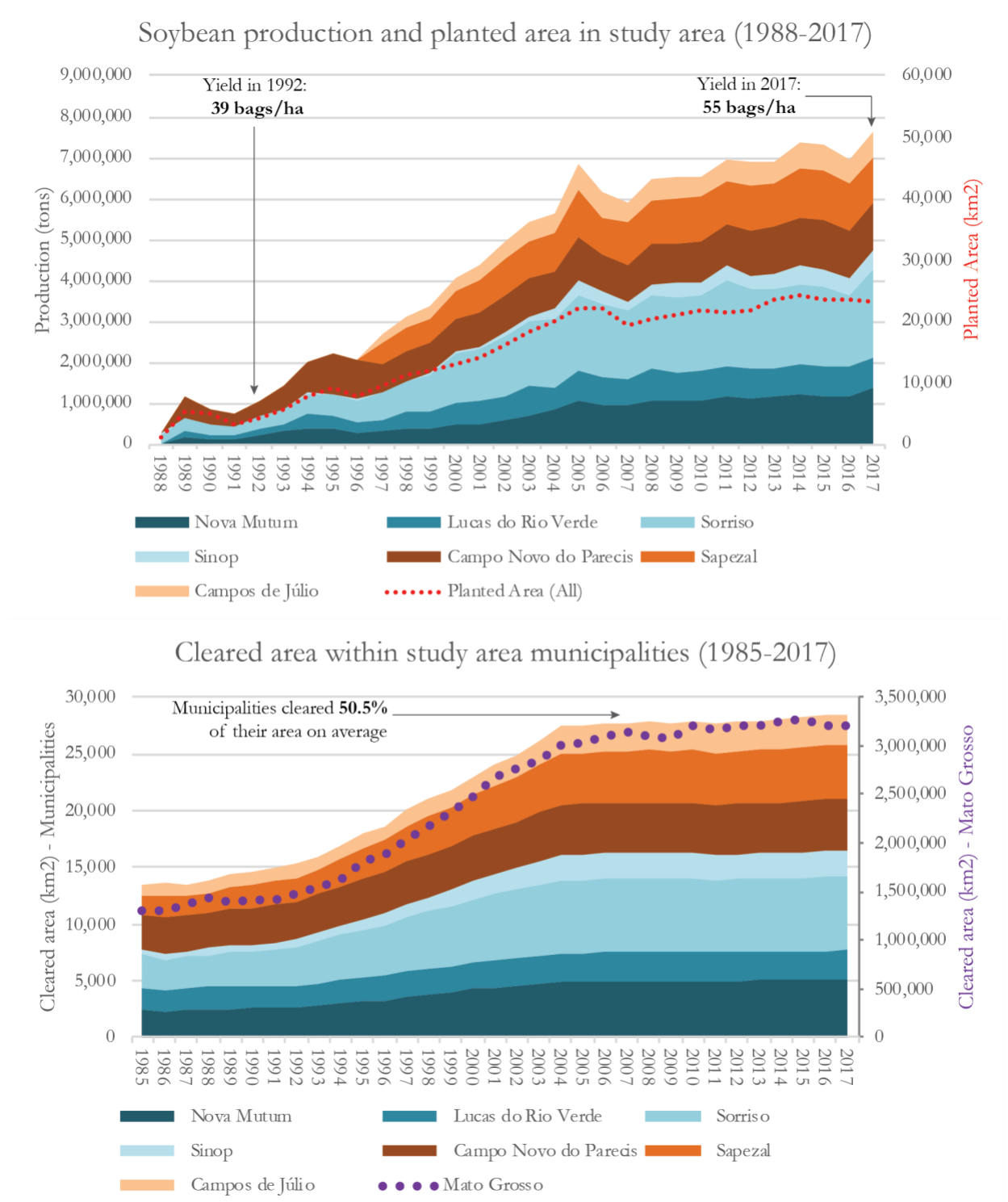


Figure 0.8. Graphs showing the increase in production and planted area in the 7 municipalities of the study area (1988-2017), and the area cleared in each municipality (1985-2017). Data from the Pesquisa Agrícola Municipal (PAM) of IBGE for production and planted areas, and from MapBiomas v3.0 for land-use. **Note**: Municipalities of the BR-163 study region appear in dark to light blue colors and municipalities of the Chapada dos Parecis appear in dark red to light red colors. The unit for yield is the soybean bag (60kg/ha). The scale for planted area in the upper graph has been chosen based on the total area covered by the 7 municipalities (56,359 km²).

As **Figure 0.7** shows, this group of municipalities represented originally an ideal mix of different vegetation covers, with areas dominated by forests, others by non-forest Cerrado vegetation, and finally a significant part under with transition vegetation (i.e. usually forests). In addition, both groups of municipalities are predominantly located within the Cerrado biome, although a significant part of some municipalities are located within the Amazon biome.[29] As I explained earlier, the distribution of forest areas across the study area, as well as the presence of both biomes, provides a setting in which there may be considerable variation in environmental policy enforcement.

Both areas are characterized by a high concentration of land ownership and the presence of numerous properties well over 1,000 hectares. Each study region presents interesting variations in terms of market access, landscape characteristics (Cerrado or forest), historical development or local political context. Finally, the common cultural background of landowners in this area is worth underlining: a vast majority of them came through successive waves of migration from agrarian and European-descent dominated states of the Southern cone of Brazil (Rio Grande do Sul, Paraná, Santa Catarina, or São Paulo) in the 1970s and 1980s.

[29] Biomes are large-scale areas that regroup several ecosystems into a similar set of ecological conditions (climate, soil types, altitude, vegetation formations). Importantly, vegetation is not the prime criterion when defining the limits of a biome (IBGE 2004). The Brazilian territory is divided into six different biomes which are (in decreasing order of size): the Amazon (4,196,943 km2, 49.3% of the territory), the Cerrado (2,036,448 km2, 23.9% of the territory), the Atlantic Forest (1,110,182 km2, 13% of the territory), the Caatinga (844,453 km2, 9.9% of the territory), the Pampa (176,496 km2, 2.1% of the territory), and the Pantanal (150,355 km2, 1.8% of the territory) for a total of 8,514,877 km^2 (IBGE 2004). This is an official estimate from IBGE. The area of biomes can vary slightly from one study to another, because of which geographical projections researchers opt for when using Geographic Information Systems (GIS). For instance, Klink and Machado (2005) give 8,534,000 km2 as the total area covered by the biomes in Brazil.

Studying the evolution of environmental behavior requires a unit of analysis as constant as possible both in time (i.e. same person) and in space (i.e. same rural property). I decided to focus on single individuals through time rather than indirectly studying how management decisions were taken over time on a single property (which may or may not have been managed by different individuals). The subject of this study is typically an individual that arrived in Mato Grosso to start activities on the rural property in the 1970s and went through successive stages of frontier development to today.[30]

Linking the behavioral characteristics of producer-landowners to actual land-use outcomes requires the collection of property boundary data. Collecting this type of confidential data is fairly difficult since landowners are generally unwilling to reveal any information about their property, as they fear legal consequences related to environmental policy enforcement (Adams 2015a), or simply mistrust the person to which they are talking.[31] A second difficulty has to do with the particular socio-economic status of the producers examined in this study. More often than not, they own several properties rather than one, either within the same municipality or state (in a few cases, landowners had rural properties outside the state). Over the course of the residence, landowners may have bought and sold several properties, and they may now occupy land that was not the first they settled on when they arrived in Mato Grosso. This means that landowners may be cultivating

[30] When the "historical" landowner-producer of the rural property was not available (e.g. absence, old age, death, etc.), I decided to interview the spouse, children, or "historical" farm operator of the farm. In a few cases, farms were so large that they were owned by a corporate entity that may or may not be linked to a historical family of landowners. In such cases, the farm operator was interviewed. Unless specified otherwise in the remainder of this dissertation, the term "producer" will be used to refer to any of these categories.

[31] Very little of this fear is however justified today since the 2012 Forest Code imposes the registration of every rural property in Brazil into an official geo-referenced register called CAR (see Chapter 3). Relying on the CAR database to identify the property boundaries belonging to a particular owner is currently unsatisfactory because (1) most property boundary declarations into the database have not been validated for accuracy yet; (2) the database is currently anonymous (property boundaries are not associated with a name). For this reason, it is necessary to get property data from the landowners themselves.

land whose native vegetation they did not clear. If such was the case, this would "invalidate" most of the measurements in terms of environmental behavior outcomes (i.e. land clearing). In order to minimize this risk, and to improve my chances of landowners entrusting me with their property boundary data, I consistently asked landowners to reveal the boundary of only one property they had, asking for the oldest one they owned (e.g. preferably the one they settled on when they arrived) and the largest one they own (to maximize the geographical "footprint" of the environmental behavior outcome I measured). If one of the two conditions was not fulfilled, I privileged the oldest property on which I could get data (versus the property size criterion), as what matters is the evolution of behavior through time.[32]

The notion of what constitutes a large-scale soybean farmer varies depending on government definitions and observers' interpretation. An agency of the Brazilian government, the National Institute for Colonization and Agrarian Reform (in Portuguese, the *Instituto Nacional para a Colonização e a Reforma Agraria* – INCRA) defines property sizes based on Fiscal Modules (FMs). The property size varies depending on the state and municipality. In Sorriso and Sinop for instance, the FM is 90 ha, whereas in other municipalities of this study it is 100 ha. Taking as a reference the 100 ha MF, the INCRA classification goes this way: small producers have an area smaller than 4 MFs (< 400 ha), medium producers are between 4 to 15 MFs (400 ha to 1,500 ha), large producers own over 15 MFs (> 1,500 ha). Thus, in the municipalities of Mato Grosso selected for this study, a large landowner would be anyone with a property over 1,500 ha.

[32] Anyone familiar with the area knows that this method may be at best imperfect, as the story of large landowners in the area is said to be one of gradual accumulation and consolidation of small land lots with one another (Almeida and Campari 1995). However, I find this version of the story "inaccurate" in many instances, as Chapter 2 will demonstrate, because many landowners in the study area held onto the first property they occupied for a long time (10-20 years), in the extent they originally acquired, before even considering purchasing a new one (which they often did not do because of family divisions).

According to the very farmers from these areas, however, 1,500 ha is still considered medium, if not small. In the minds of producers, large corresponds to an area over 3,000 or 5,000 ha, with very large producers being over 10,000 ha. The Agricultural Census led by the IBGE periodically (i.e. every 10 years or so) delineates property size categories that differs from INCRA's classification. The upper tier of that classification delineates categories between 500 to 1,000 ha, 1,000 to 2,500 ha, 2,500 to 10,000 ha, and 10,000 and above. In order to strike a balance between these classifications and ensure some level of comparability with the data on properties collected by governmental bodies, I chose to set the threshold for the selection of farmers participating in the study to 2,000 hectares. To be included in the sample, all farmers' primary activity had to be soybean production.

The target number of interviews per municipality was set to 15 (n=100 in total), in order to get a balanced picture of large-scale soybean producers within the study region (**Figure 0.9** shows the approximative geographical distribution of 65 property polygons of landowners interviewed during fieldwork). According to the preliminary results of the 2017 Agricultural Census, there were 4,365 landowners with more than 2,500 hectares of land (9,497 if we include those with properties between 1,000 to 2,500 ha) in Mato Grosso (IBGE 2017). Not all of these producers are soybean producers, many of them may be cattle-ranchers. In the study area of 7 municipalities, there were 385 producers with more than 2,500 ha (793 producers if we adopt a 1,000 ha threshold). As a result, a sample of 100 producers would represent between 25.9% (with a 2,500 ha threshold) and 12% (with a 1,000 ha threshold) of the population of large-scale landowners

(IBGE 2017).[33] Although the distribution of these landowners differs from one municipality to the other (e.g. there are 105 producers with 2,500 ha or more in Sorriso while there are only 53 in Sapezal), I kept the number of producers to be sampled by municipality constant. The final number of producers interviewed for this study was 104.

The period of analysis adopted for this study extends from the year 1985 to 2015. The availability of satellite images for the land-use mapping of rural properties largely influenced the choice of time period. Nonetheless, this time period corresponds more or less to the time period of colonization of these areas of Mato Grosso, as the first colonizers coming from the South arrived at the end of the 1970s, but the bulk of them arrived in the 1980s (Jepson 2006a, 2006b; Almeida and Campari 1995; Dubreuil et al. 2009; Dubreuil, Bariou, Passos Dos, et al. 2005). Thus, this time window enables the analysis of the evolution of producers' environmental behavior over different changes in biophysical, economic, and institutional factors.

[33] Estimates based on IBGE's 2017 Agricultural Census.

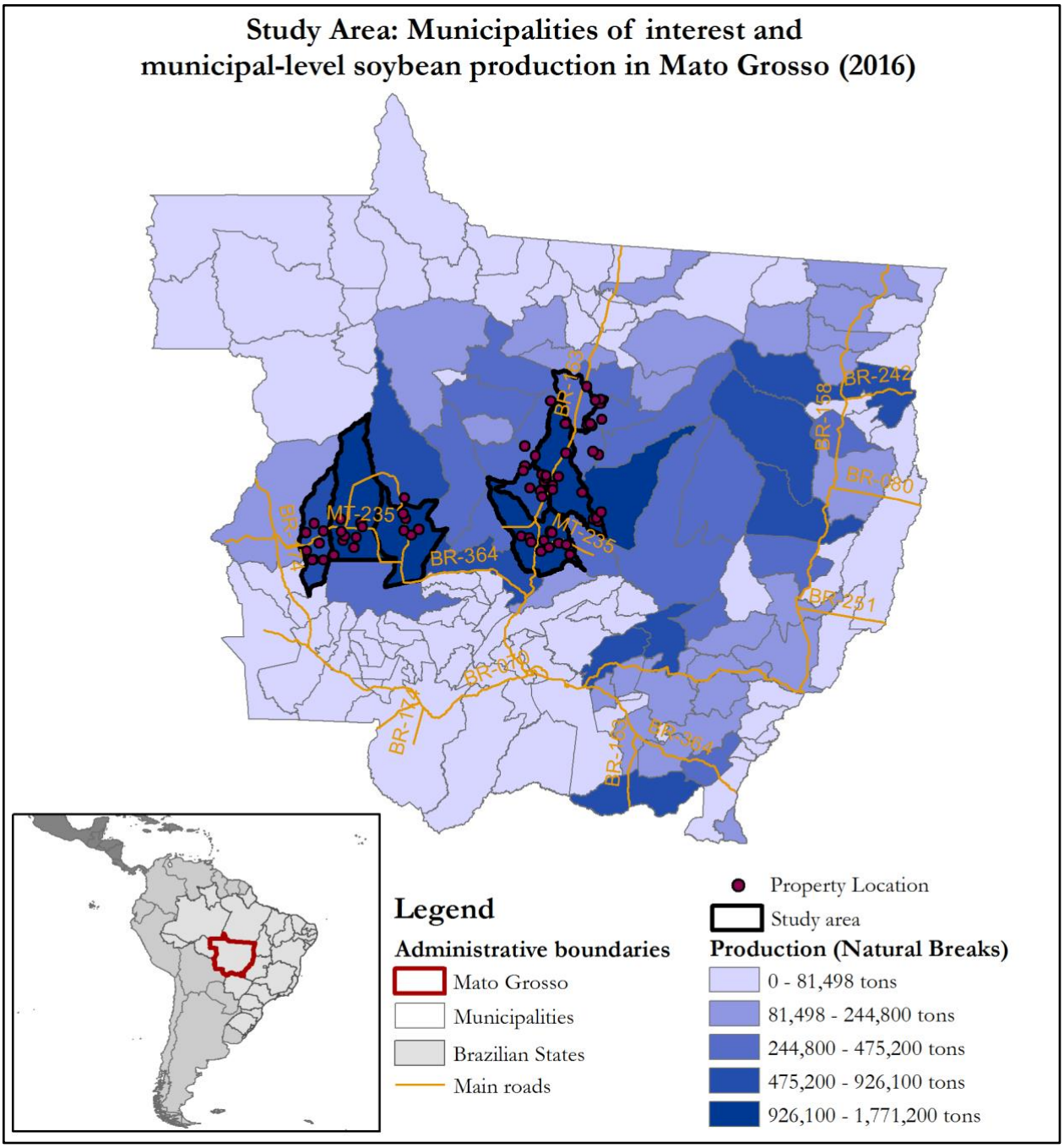


Figure 0.9. Soybean production volume (in tons) in 2016 and property location of interviewees. The soybean production data comes from IBGE's Municipal Agricultural Production **Note**: The location of 65 properties (which information was released by 56 landowners) are indicated on the map by a coarse dot that does not enable the identification of the exact location of the property (See Chapter 4). The actual location of any property is not displayed in this dissertation to respect the anonymity and confidentiality of the information provided by landowners.

6. RESEARCH CONTEXT: MISTRUST TOWARD THE EUROPEAN WHITE MALE (AND MOST LIKELY EVERYONE ELSE)

6.1. A MULTI-METHODS APPROACH: INTERVIEWS, LAND- COVER CHANGE, AND STATISTICAL ANALYSIS

The research was carried out over two field trips to Brazil between May and July 2016 and February to July 2017 (2.5 months and 6 months respectively). During the first "pre-dissertation" field research trip (May-July 2016), I visited various cities related to the soybean agribusiness in Brazil (São Paulo, Brasília, and Cuiabá). I met with the executive director of the soybean producers association of Brazil (*Associação dos Produtores de Soja e Milho – Brasil* – APROSOJA – BRASIL), the larger declination of the soybean producers association of Mato Grosso (APROSOJA-MT). This contact recommend that I meet with the president of APROSOJA-MT as well as the chairman of the Agriculture and Ranching Federation of Mato Grosso (*Federação da Agricultura e Pecuária do Estado de Mato Grosso* - FAMATO). I met with the chairman of the FAMATO in June 2016 to explain the research project and ask for his support in contacting large-scale soybean producers in the municipalities of the study. He provided me with the contacts of the presidents of the rural producer unions of each municipality (called *sindicato rural*, and referred hereafter as "*sindicato*" in this dissertation). I then travelled and met with most of the presidents of these *sindicatos* and asked them for a list of producers (and their cell phone numbers) owning more than 2,000 ha in the municipality. Some presidents provided me with the list during my first field research trip while others provided me with the list only upon my return during the second trip.

I applied a semi-structured questionnaire to 104 producers in the study area.[34] The questionnaire (**See Annex**) was composed of two stages. In the unstructured, first stage of the interview, I asked producers to tell me about their personal stories in the region and marked down on a table the key elements of their lives in a chronological order, recording personal information such as: movements within Brazil, time of arrival in a region, education degree, family events, property acquisitions, native vegetation clearing, etc. In the structured, second stage of the interview, I asked a series of questions relating mostly to the property chosen for analysis (according to the criteria of historicity and geographical footprint detailed above). This second part was divided into two subparts, one more quantitative and one more qualitative. Among the elements assessed in the first subpart, there were data about: properties owned by the farmers, crop area and type, funding structure of the farm, compliance with the environmental laws, agricultural and conservation practices (e.g. no till systems, forest restoration, inputs use, etc.), participation in associations or professional trainings, perceptions about public policies (e.g. using Likert scales from 1 to 5). In the second subpart, I asked producers information about and their perceptions of agricultural practices, deforestation, definition of "environment," the role of different conservation requirements mandated by law, the continuation of their activities in the future, and their information sources.

The interviews featured in this dissertation were all carried out during the second field research trip (February-July 2017). The location of the interviews with producers varied greatly: 27 were on-farm visits, 36 were at their offices, 33 at the *sindicato*, and 8 were conducted at other

[34] The study received an exempt type IRB approval (n° 1604625766) at Indiana University – Bloomington, and oral consent was gathered from participants prior to starting the questionnaire.

locations.[35] The average duration of interviews was 104 minutes (1 hour and 44 minutes) with the shortest interview lasting 36 minutes and the longest lasting 270 minutes (4 hours and 30 minutes).[36]

At the end of each interview, I asked the authorization of landowners to use their property boundaries to analyze land-use change history. Only 56 producers agreed to reveal this information while the rest either refused or did not end up delivering the information.[37] As I explain in further details in Chapter 4, I carried with me during the interview large size maps of the municipalities and their surroundings in a document carrier which looked like a large black tube (which the farmers nicknamed the "bazooka"). I asked producers to locate their properties on the map and draw their boundaries. Although it proved difficult at times to locate the property given the small size of geographical features like roads, interviewees had no trouble drawing their property boundaries with accuracy once they located a landmark they were familiar with (e.g. a road or a river). Rural properties often follow very simple boundaries due to the settlement pattern in the region and their large size. Since the region is riddled with several streams and rivers descending toward the Amazon river, most roads were built to sit at the highest and most central point between two water bodies. As a result, property lots were often designated on each side of the road and went down to the nearest stream. As a result, the road represents one side of the property while the river draws the opposite side.

[35] 5 interviews happened at the house of the producers, 2 at a restaurant, and finally 1 in a car. The car I used to visit these farmers broke down in the middle of a farm and the producer I interviewed drove me to town to get help.

[36] In full transparency, I even cut the lunch break time for this one, as I ended up spending most of the day with this producer.

[37] Several farmers agreed to communicate this information to me at the end of the interview but preferred to provide me with maps they already had or official documents that showed the GPS coordinates of their properties. However, it proved difficult to contact some of them afterwards to gather these documents.

Once returned from fieldwork, I transferred this data from paper to computer using Google Earth Pro (Version 7.3.2.5491) to draw polygons that represented the farm boundaries. In total, 65 different property polygons were drawn (for a total of 56 landowner families, representing 67 interviewees) which means that some landowners had discontinued properties or revealed information about more than one property. I included all the polygons into the analysis since it represented more information.[38]

I then acquired satellite images from the Landsat 5 and Landsat 8 satellites to cover the entire study period (1985 to 2015). I visually classified the land cover by 5-year time periods (1985, 1990, 1995, 2000, 2005, 2010, 2015). Although a lengthy process, the visual land-use classification provided with a higher level of accuracy at the property level than unsupervised and supervised classification. I provide in Chapter 4 a complete explanation of the reasons for choosing this methodology and a step-by-step description of this process. The result of this process was a land-use cover dataset with 7 observations (i.e. time points) containing 4 classes (agriculture, forests, Cerrado, herbaceous/woody covers) and 3 land-cover change classes (forest clearing, Cerrado land clearing, and vegetation regrowth).

Finally, I use statistical regression analysis in Chapter 6 to disentangle the factors affecting the adoption of good agricultural practices (GAPs) [39] by large-scale soybean producers. I codify the results of the semi-structured questionnaires to examine the relative influence of socio-economic

[38] 5 landowners had non-contiguous properties and 2 other landowners gave me information about all the properties they acquired over time.
[39] Defined in Chapter 6

and pro-environmental value variables on the decision to adopt different groups of GAPs. Further methodological details are provided in each respective chapter.

6.2. POSITIONALITY: MISTRUST AND A WAY TO "FIX" IT

As put by Kapiszewski et al., "many scholars believe that a researcher's self-presentation and personality, and a respondent's perception of the interviewer's identity and personal traits (e.g. her gender, ethnicity, marital status, educational level, socio-economic status, and nationality) – in interaction with the research context – shape the interpersonal dynamic of an interview and thus the data collected through it" (Kapiszewski, MacLean, and Read 2015: 222). Like other researchers conducting fieldwork about soybean producers in Brazil (e.g. Gaspar 2013), I also believe that such factors, referred to as "positionality", matter a great deal in the type of access and information gathered by researchers.

Field research does not occur in the vacuum of laboratories. Many parameters influenced this research, the respective influence of which could be debated in a separate book. I nonetheless want to outline here the elements that -I believe- have most impacted the unfolding of interviews and the resulting content. I will first describe briefly the context in which I did the research and what I believe was the perception soybean producers had of me. Second, I will expand briefly on the approach I adopted to compensate for some of the biases introduced by my "identity" into this research.

Farmers in Brazil, especially in the Legal Amazon, and particularly large-scale ones, are often associated by the national and international public opinion with negative outcomes such as large-

scale deforestation, rural conflicts, chemical inputs overuse, and slave labor issues (Rainforest Foundation Norway 2018). Media and environmental NGO reports such negative outcomes, and this political pressure has translated in recent times into market restrictions and public sanctions for farmers (e.g. Soybean Moratorium, "dirty list" of slave labor, etc.). In Mato Grosso, like in other Brazilian Amazon areas, these reports have often been made by individuals (journalists, academic or NGO researchers) who visited farms and interviewed landowners to document the nature of the human-environment interaction in these areas. More often than not, bad press resulted from such interviews, be it about deforestation or the conflicts between large landowners and small landowners (or landless peasants). Furthermore, conflicts with indigenous people erupted in many places in Mato Grosso, especially around the Xingu Indigenous Park area where soybean expanded quickly in the 1990s and 2000s (Brondizio, Ostrom, and Young 2009).

As a result, farmers have been increasingly hesitant about meeting with outsiders, and have also developed a certain mistrust toward European or American Environmental NGOs which some see as manipulated by OECD-country money to slow down agricultural development in Brazil. In their view, they perceive these "European-backed" NGOs as curtailing their "right to legal deforestation"[40] and claim that Europe cleared all their forests before coming to Brazil to lecture them.[41] The recent signing by 40 organizations (mostly environmental NGOs) on September 11, 2017 of a "manifesto" for zero-deforestation in the Cerrado biome worsened this perception. The president of APROSOJA-MT announced immediately a "moratorium on NGOs" (in Portuguese

[40] Authorized by environmental laws in theory, as long as respective environmental agencies approve a landowner's clearing plan and that it falls within the area outside of conservation requirements.

[41] Although Europe cleared a large extent of its native vegetation, woodland covers currently 38% of the European Union's total area (this area is much larger if we include all countries in continental Europe), "only 4% has not been modified by human intervention" (Breuer 2019)

"Moratoria das ONGs", Personal communication with an interviewee), referring to the interruption of any communication between the farmers' association and environmental NGOs. As a European white male visiting soybean producers for an extended period of time in the middle of their harvest season and beyond, one farmer may have well been very suspicious of my activities. Getting the trust of farmers proved challenging but not impossible. A series of intentional (and non-intentional) actions from my end resulted in my access to this population.

First, I mainly got producers' contacts through the local *sindicato*[42] and was recommended by the president of this institution in each municipality. My previous identification by the leadership of the soybean sector (through various visits to institutions like APROSOJA-Brasil, APROSOJA-MT, FAMATO) helped convince the presidents of the *sindicato* I visited of my genuine scholarly interest in their history and land-use behavior. Second, I spoke Portuguese fluently which facilitated greatly the communication flow between me and the interviewees. Third, I always started interviews with a straightforward explanation of my research and its objectives to producers. Producers in almost all cases welcomed this and granted me the interview. Only one producer told me constantly that "he would refuse to give me any information" but we ended up talking for two hours while he gave me information. They often asked if I was an environmentalist, question to which I generally responded something along the lines of: "Yes, I believe we should preserve the environment, but here I am interested by your story and your point of view, and I am dedicated to do it in the most impartial way possible."

[42] In very few instances I contacted producers who were recommended to me by producers I had interviewed. However, most of the time, these farmers were already on the list provided by the *sindicato*.

An important point in the interview strategy was to ask producers first about their history rather than diving into questions related to their property, their perceptions of environmental policies, or other types of in-depth questions. This seemed to give farmers more confidence about the purpose of my visit in the region, since I was sincerely interested to know what their personal challenges in settling down in an Amazon frontier had been. The great personal stories they shared with me led them sometimes to evoke with emotion some painful memories, and I may say that these are the moments that I look back to as the richest and most honest experience I had while doing research there.

Finally, I would be at fault not to mention a critical element of the research strategy that greatly affected my positionality in the field: my azure-blue 1976 Volkswagen Beetle ("Fusca" in Portuguese). This car was not only critical for allowing me to move around and visit farmers at the places where interviews took place,[43] it also created an unexpected relationship with the producers. First, most producers complain about receiving too many visits from salesmen (inputs resellers). As they usually arrive in brand new white pick-up trucks, arriving in a small Beetle conveyed to them the feeling that I was not "another salesman," in addition to being extremely uncommon for people to travel in AC-less cars in the region. It did more than that, however.

Second, many of these producers came from the South of this area by driving up with their vehicle in the 1970s and 1980s, times at which the "fusca" was the car most sold in the country (**See Figure**

[43] As a cash-stripped graduate student, still benefiting from sufficient and "comfortable" U.S. and French academic funding, I was not able to rent a car for doing my field research. Hence came the idea to buy a car with my own savings, which costs I would recover later, and fix it myself with the help of the locals. With the long-time dream of buying a Brazilian "fusca"

0.10). Although some came with Ford pick-up trucks, many came with beetles as it was an affordable car at the time. As a result of their agricultural "success story" and their narratives about the "pioneerism" they proved by settling there, farmers in the area have a particular emotional link with that car. They also recall the stories of their fathers or uncles who went to look for land in various part of the country by driving these cars.

Figure 0.10. Pictures of farmers with transportation means. On the left, a family of farmers sitting on a Ford pick-up truck and posing for a picture in the Cerrado areas of Nova Mutum in the late-1970s early-1980s. On the right, a series of trucks stuck in the mud and a man driving a white VW beetle getting out to help, on the yet unpaved BR-163 highway (Pictures courtesy of interviewee 001).

As a result, I could often engage the conversation and gain the sympathy of interviewees by exchanging on colonization or car stories. They would be very surprised that I chose to visit them using a car without AC, and the fact that this car is still affordable today may have finally managed to convince them that no "foreign money" was behind my work.[44]

[44] In many interviews, producers mentioned how they saw the action of environmental NGOs as being manipulated by American or European businesses trying to hinder the competition of Brazilian agriculture.

7. CONTRIBUTIONS

This dissertation fills several research gaps by looking at what motivates the environmental conservation behavior of large-scale soybean farmers in Mato Grosso, examining their behavior as part of broader landscape, cultural, and technological processes. What follows is a brief summary of the dissertation chapters and their respective contributions to academic debates.

7.1. CHAPTER 1

In chapter 1, I argue that the colonization of the Amazon-Cerrado transition area of Mato Grosso occupies a unique place in the westward colonization history of Brazil. Why were these specific areas of Mato Grosso the ones to become the center of soybean production and lasting economic success? Until the end of the 1970s, the Chapada dos Parecis and Alto Teles Pires (BR-163 region) were stuck in between two distinct fronts: the expansion on the Cerrados of the Center-west on the one hand, and the creation of colonization "islands" based on perennials, rice, and cattle-ranching to the North. Although a few existing institutions already allowed colonization since the mid-19th century (especially through the spontaneous settlement of land via *posse*), the (weak) state and federal efforts to colonize Mato Grosso did not translate into much migration by the arrival of the military regime in 1964. Armed with a geopolitical vision that commands the occupation of the western and northern areas of Brazil, the federal government created development programs and associated federal agencies to fund the expansion of agriculture and cattle-ranching, offered tax incentives, and added infrastructure connecting the Amazon region to the rest of the country (with the successive PINs). The military government reinforced private colonization of Mato Grosso through *colonizadoras*. While most of them were originally located in the forested areas of northern Mato Grosso, a slim portion of colonization projects took place in the Amazon-Cerrado transition areas, especially along the BR-163. The key difference with other colonization projects

was that these ones were oriented toward agriculture. However, I argue that the mainstream explanation according to which private colonization firms explain the success of Mato Grosso's colonization is incomplete. Despite the fact that such organizations were present in the BR-163 area but not in the Chapada dos Parecis area, both areas still reached similar agricultural development. This lower influence of colonization firms than previously thought may well have to do with the fact that they represented one factor among many in the colonization of these areas. The improvements of agricultural technology for the Cerrado was, for instance, one of the key development that allowed agriculture to be profitable in the study area.

7.2. CHAPTER 2

The expansion of soybean onto the Amazon-Cerrado transition areas of Mato Grosso was carried out by a particular group of colonizers dedicated to cultivating crops (as opposed to cattle-ranching) in a new "Eldorado" of farming. Although the large-scale soybean producers of today presented slight differences in socio-economic status when they arrived, the overwhelming majority came from smallholder families from the South (Rio Grande do Sul, Santa Catarina, Paraná) and rarely owned more than a few hectares. Re-constituting the life trajectory of these colonizers, it is possible to discern a few elements that challenge current narratives about the region. First, migration was often an "extended-family" endeavor, colonizers usually arrived with brothers, cousins, friends, or business partners to purchase their first lots or take control over public lands (*terras devolutas*). Second, farmers arrived mostly in the 1980s and accessed areas under different tenure types. This contrasts with the picture of a region colonized only by private colonization firms, in which there is a "turnover" cycle where newer capitalized farmers buy up the land of failing or weak farmers who cleared land for them. Despite state support, producers

arriving in Mato Grosso in the late-1970s and 1980s were gambling when they decided to settle in the Amazon-Cerrado transition areas. Many failed, but those who remained transformed economic difficulties into opportunities, accumulated land, and now constitute a well-informed population of modern soybean producers. In particular, their strong determination to transform the region combined with technological advances helped them overcome several limitations to local agriculture. Other regions received state support but did not transform it into similar economic success.

7.3. CHAPTER 3

The colonization and subsequent rapid expansion of soybean in the Amazon-Cerrado transition areas of Mato Grosso in the 1990s and early 2000s led to extensive deforestation. In chapter 3 I analyze the evolution of Brazilian environmental policy at the federal- and state-level. Because the anti-deforestation efforts of the federal government focused on the Amazon biome and did not have much enforcement power until 2004, deforestation went rampant until then, especially in the Amazon-Cerrado transition areas of Mato Grosso. In addition, I argue that inconsistencies caused by multiple revisions of the Forest Code, coupled with diverging interpretations of environmental policy following the decentralization of competencies from the federal- to the state-level, created major uncertainty for producers. Although some took advantage of this uncertainty (some even sought them), it hindered the compliance willingness of others. Deforestation rates nonetheless dropped after around 2005. There is considerable uncertainty about the cause of such a drop in the Amazon-Cerrado transition area because environmental policy enforcement operations mostly concentrated in the Amazon biome, and satellite-based monitoring systems were unable to accurately identify land clearing in the Cerrado. Furthermore, a majority of studies about the

respective efficiency of environmental policies and zero-deforestation market-based initiatives relied on PRODES data (with some major exceptions), leaving knowledge gaps about which policy or initiative *caused* the deforestation decrease.

7.4. CHAPTER 4

Soybean producers shared a common plan for clearing native vegetation at a steady pace to make room for crops and to face an ever-increasing demand for soybean, regardless of their location in the Cerrado or Amazon biome. If all producers cleared extensively, the results of the analysis point out several qualitative (i.e. type of clearing), quantitative (i.e. extent of clearing), and temporal (i.e. timing of clearing) differences. For instance, rural properties in the Chapada dos Parecis region cleared fewer forests than those in the BR-163 area, something partly explained by the differences in initial native vegetation cover at the moment of soybean expansion. Rural properties in both biomes generally disregarded the changes in native vegetation conservation requirements, and there were no significant differences in the clearing thresholds (i.e. maximum) attained by properties of either biomes, attesting to a common plan to produce crops on large areas. A slim portion of rural properties in both biomes decided to cross the threshold authorized by the law right at the moment the LR percentage changed, while many had already cleared more than was previously authorized. The effects of environmental policies are difficult to analyze since properties tended to stop clearing at different times, some much before the late 1990s. Many also stopped clearing regardless of the extent deforested, which means that it is not necessarily because landowners reached the geographical limits of their property that they stopped clearing (although they may be constrained by poor soil quality, the fact that properties have different clearing threshold does not support this assumption very well). These observations seem to be confirmed

by soybean producers' perceptions of environmental policies. Apart from Sinop and to some extent Sorriso (partly encompassed in the Amazon biome), producers did not feel like the environmental policies had much impact on deforestation reduction.

7.5. CHAPTER 5

In Chapter 5 (inserted as a separate paper in the dissertation), I examine the evolution of the production strategies of large-scale soybean farmers in Mato Grosso along the history of the frontier. The research questions are: (i) what are the production strategies that help explain the transition toward intensification and the ensuing land sparing?; (ii) what can we learn from the environmental and financial risk tradeoffs associated with each strategy? This chapter combines this dissertation dataset with another dataset of semi-structured interviews with producers and policy-makers in Mato Grosso (n= 103 + 31) provided by co-authors, as well as quantitative data (land-use dataset and agricultural census). We found that large-scale producers went through 5 different production strategies over time. These strategies translate different visions of how a property can be profitable, and help explain why producers may not have found it attractive to further deforest land after 2005. From production strategies based on geographical expansion in the early stages of colonization, producers have gradually re-focused their efforts on producing the maximum output at the property-level, and then at the plot-level, taking advantage of differences in yield within their farms. It turns out that such strategies differ significantly in terms of financial and environmental risks (i.e. impacts), and some strategies seem more likely to reduce both risks than others. Some producers now opt for diversifying their production systems and adopting medium- to long-term production strategies that lead to taking part of their land out of production

for one or more years. We note however that such strategies are contingent to technological, economic, and institutional conditions, and may well revert if such conditions change.

7.6. CHAPTER 6

The final chapter examines how environmental perceptions and values of producers evolved along changes in production strategies, while explaining the types of good agricultural practices (GAP) adopted by producers today. I argue that it is possible to understand the 'productivist' identity of large-scale soybean producers through their perceptions of the environment and their environmental values. By asking producers how they felt about deforestation impacts (both positive and negative) I explored the way they re-contextualize their production role when confronted with the impacts of agricultural expansion over native vegetation. Producers tend to boast about the positive contribution they make to society through soybean agriculture and minimize their negative impacts through an environmental rhetoric putting forth their caring for soil health. Yet they also demonstrated a real concern for environmental impacts. Producers appeared to strongly embrace the importance of forest conservation requirements as they related to riparian forests areas (for the protection of water bodies) but discussed the obligation to conserve a certain percentage of their property under native vegetation (i.e. Legal Reserve). I then examine the impact that the pro-environmental values of large-scale soybean producers have on the adoption of GAPs. I find pro-environmental values influence such adoption for conservation-related GAPs, but not for GAPs related to soil management or agrochemical use. If there is some evidence supporting the idea that pro-environmental values play an important role in farmers decision-making, it is definitely for a minority of farmers.

Chapter 1. The colonization of Mato Grosso: Soybean production in the Amazon-Cerrado transition area

Simply looking over a map of Brazil, it would not be obvious why the leading soybean producing region of Brazil is tucked against the Amazon forest, or at least, where the forest (officially) starts. In truth, this agricultural region is located in an area of transition between the two largest ecological biomes of Latin America: the Amazon and the Cerrado biomes. In the 1960s, few may have guessed that the future of Brazilian agriculture would sprawl there. The first attempts at modern agricultural production in the area rested on low-intensity cattle-ranching and rice cultivation, which exhausted soils in a mere two years. Most attempts to turn this area of acidic soils into productive fields were disappointing at best since farmers did not use many inputs and ended degrading the soils rapidly (Empinotti 2015). Amazon colonizers preferred to move north to denser forests driven by federal incentives to occupy land and the lure of timber, gold, and fertile land easily turned into pastures.

Nonetheless, some observers had a different opinion about that area. A farmer once told me in Nova Mutum that a Japanese agronomist from the FAO[45] visited the region in the 1970s and told them that the area around the BR-163 highway from Nova Mutum to Sinop would eventually become "o celeiro do mundo," the world's bread-basket [ITW n°006]. This sentiment applies today because these areas appear as well-fit for contemporary capitalistic agricultural production. The challenge of acidic soils has been overcome by progress in soil acidity correction of the Cerrado in the 1960s while the challenge of planting commodity crops in tropical latitudes has been remedied by new soybean varieties in the late 1970s (Wilkinson and Sorj 1992; Spehar 1995).

[45] United Nations Food and Agricultural Organization (FAO)

Equipped with this new technology package also including modern inputs, modern agriculture took advantage of the biophysical characteristics of these plateaus: large flat areas suitable for large-scale mechanization and abundant rainfall for six months a year.

However, what is 'obvious' today in terms of agricultural potential was not yesterday, and this bears considerable implications for the type of colonizers who were attracted to this region and who differed greatly from other colonization projects in Mato Grosso. In this chapter, I summarize the changes in federal colonization policies of westward expansion in the mid-1970s and how they led to the occupation of the Center-North area (along the BR-163) and the Western area of Mato Grosso. Contrary to settlers in other areas of the Amazon, colonizers from southern Brazil came straight for predominantly crop-based production projects (as opposed to cattle-ranching or perennials). This chapter argues that their success was due to the progressive alignment of enabling conditions for agriculture, including favorable state policies and geopolitical conditions. In contrast, the next chapter (Chapter 2) will argue that the specific social, economic and cultural traits of this group of colonizers from the South were instrumental to the colonization of the area. What was the respective role of each of these conditions -economic or other- in the commercial success of soybean production will perhaps always be subject to debate. However, no alternative explanation should obscure the fact that some of the conditions "enabling" agriculture in the area are part of a unique story in Brazilian, if not Latin American, development, including the challenge of turning an immense frontier into an economically prosperous region confronted by this group. Few other regions in the Amazon present the same degree of lasting economic success contrasted with the social (Rachael D. Garrett and Rausch 2016; Martinelli et al. 2017) and environmental adverse consequences that agricultural expansion has caused (Philip M. Fearnside 2001).

This chapter thus explores the following questions: Why did this group of large-scale soybean farmers get in this specific area of the Legal Amazon? What were the conditions (institutional, economic, biophysical, …) explaining why they chose these two plateaus specifically, and how much can these initial conditions explain their success? To explore these questions and their many ramifications, the chapter is divided in two main parts.

The first part replaces the history of the BR-163 highway and Chapada dos Parecis areas within the broader history of Amazon colonization, using the start of the military dictatorship in Brazil as the key turning point. Despite colonization efforts extending back to even before the efforts toward westward expansion of the Estado Novo in the 1930s, it is only after the impulse given under the military dictatorship that the colonization took off. The second section examines the key elements that distinguish the study area of the BR-163 and the Chapada dos Parecis from the rest of the colonization history of Mato Grosso. This section explores why a specific population of smallholder farmers from the South chose to settle in the study area. They key point here is that the colonization firms and colonizers arriving in this area had the project to carry out agriculture (and not cattle-ranching) from the very start.

1. The colonization of the Amazon and the Cerrado

The coup in 1964 that established a military regime was the key turning point, or "*divisor das águas*" in Portuguese, for the colonization of the Amazon. Until then, previous political leaderships valued the region for resource extraction and -limitedly so- for national security, and development booms were fairly isolated from one another. It is important to distinguish Mato Grosso from the development story of the Amazon on the one hand and that of the Cerrado on the

other. Despite formally belonging to the Legal Amazon, the state was only marginally affected by plans to develop the Amazon until the 1970s. During that period, Mato Grosso was "stuck between" two development waves.

Since the mid-nineteenth century in the northwest areas of the country, the Amazon supported the national economy through the production of commodities following boom-bust cycles (e.g. rubber, coffee), and the extraction of precious materials (e.g. gold, diamonds). During this period, these various undertakings did not translate into generalized stable human settlements (with the exceptions of indigenous peoples who had been there for thousands of years, and the cities of Manaus and Belém). The development of the cities of Manaus and Belém were two exceptions to this. South-east of Mato Grosso, the technological revolutions in Cerrado agriculture and the installation of the country's new capital, Brasília, helped explain the expansion and colonization of the neighboring states of Goiás and Mato Grosso do Sul. However, this expansion limitedly affected Mato Grosso until the 1970s. The area surrounding the municipality of Rondonópolis is one of the first to illustrate the adoption of Cerrado agriculture at the time.

In 1970, the Northern region (*Região Norte)* of Brazil (representing the Legal Amazon without Mato Grosso) had only 3.6 million (m) inhabitants. In 2010, this same region had 15.8m inhabitants. Similarly, for the Center-West region (*Região Centro-Oeste)* comprising the states of Mato Grosso, Mato Grosso do Sul, Goiás,[46] and the Federal District,[47] the total population in 1970

[46] Mato Grosso do Sul and Goiás do not belong administratively to the Legal Amazon, but they are relevant here since the Center-West region of Brazil was also one affected by the colonization efforts *in general* inBrazil during the same period, benefitting from various official development programs.

[47] The Federal District ("Distrito Federal" in Portuguese) is comprised within the state of Goiás and delineated the territory of the new capital of Brasília. It is comparable in organization to the District of Columbia in the United States for the city of Washington.

was 5m inhabitants as compared to 14m in 2010. These two regions have been the fastest growing regions in terms of population over the 1970-2010 period and went from representing 9% of the total population of Brazil in 1970 to around 15% in 2010 (IBGE 2018). This population shift demonstrates that the westward expansion of Brazil into the Cerrado, with the founding of Brasília in the middle, has no precedent in the country's history.

1.1. PRE-MILITARY REGIME PERIOD (<1964): AGRICULTURE EXPANSION IN THE CERRADO, FIRST INCURSIONS OF CATTLE-RANCHING IN THE AMAZON, LAND TENURE INSECURITY AND CORRUPTION

1.1.1. Federal efforts to occupy the Center-West and Amazon regions: the March to the West and the SPVEA

Getúlio Vargas was the first president to launch a comprehensive initiative to trigger the occupation of the Center-West region of Brazil, aspiring one day to occupy the entire Amazon. Unlike others before him, Vargas recognized the geopolitical rationale for occupying these regions of Brazil, both in terms of national security and economic potential. On December 31, 1937, he announced on national radio the "March to the West," a plan to conquer what he deemed to be an "empty space" by favoring small-scale agriculture (Moreno 1999). The plan included the construction of infrastructure (roads) and the creation of agricultural colonies (*Colônias Agrícolas Nacionais - CAN*) exemplified by the colony of Dourados established in 1943 in Mato Grosso do Sul. However, the objective of the "March to the West" was not to develop the Amazon region directly, but this region would probably have been the "next step" for Vargas. He indeed demonstrated this by symbolic gestures (with the 1940 *Rio Amazonas* speech in Manaus) (Stella 2009) with some infrastructures project such as the construction of the Manaus airport and the projected construction of a road connecting the city to Porto Velho in Rondônia (abandoned in 1946) (Le Tourneau unpublished).

After World War II, a principle in the new Brazilian Constitution of 1946[48] reallocated public funds toward the Amazon region by assigning 3% of all federal revenues toward its development. However, little was implemented before the creation of the Superintendence for the Development of the Amazon (*Superintendencia do Plano de Valorização econômica da Amazônia – SPVEA)* in 1953.[49] The goal of the SPVEA was to support Amazon colonization by building road and energy infrastructure and providing support to colonizers through credit, health services, and research (scientific and geographic) (Le Tourneau unpublished). This new policy also marked the creation of a new administrative unit in Brazil: The *Legal Amazon*. The Legal Amazon was created to delineate the territorial scope of development incentives provided by the SPVEA and today comprises almost 9 states (from West to East): Acre, Amazonas, Roraima, Rondônia, Pará, Amapá, Mato Grosso, Tocantins, and the state of Maranhão up to the 44° meridian west of Greenwich. The investments of SPVEA, which was notoriously disorganized and corrupted, remained concentrated in Belém and little was allocated to Mato Grosso (Rivière d'Arc 1977). The organization also suffered organizational problems such as a year-based budgeting precluding any long-term planning. It also had very little control over how the funds were disbursed since "75 to 85 percent of its funds were spent through contracts with other organs in the region (…)" (Mahar 1979: 8) . The SPVEA found its most fruitful application when the government of President Juscelino Kubitschek moved the capital to Brasília, in Goiás, and constructed the Brasília-Belém highway. Inaugurated in 1960, this highway was the first to penetrate the Amazon.

[48] Constitution of September 18, 1946 (Constituição dos Estados Unidos do Brasil do 18 de setembro de 1946)
[49] Law n°1.806 of January 6, 1953

During this period of federal government investment in the occupation of the Center-West region and the Amazon, the former turned to be the largest beneficiary. Most of the CANs created in the 1940s were in Mato Grosso do Sul,[50] and the others were created in Taquari-Mirim and Ministro João Alberto (today, Nova Xavantina) (Galvão 2013). Colonization in Mato Grosso did not begin until the 1950s, when the state government started a project in the area between Cuiabá and Rondonópolis within the São Lourenço river valley (south of the actual state of Mato Grosso). There, a colonization project run by a corporation (*colonizadora)* called CIPA (*Colonizadora Industrial, Pastoril, e Agrícola Ltda*) attempted to attract Japanese colonizers from the state of São Paulo to support rubber extraction activities. The project was however abandoned in the 1970s. The only noticeable advance farther north than this, was the Roncador-Xingu expedition[51] in 1940 in northeast Mato Grosso, which initiated "first contacts" with indigenous tribes of the Xingu and paved the way to the colonization of the Araguaia Valley (Moreno 1999).

1.1.2. Spontaneous and state-initiated colonization: critical role of land tenure laws and emergence of the *colonizadora* model

Though the federal government did not initiate many colonization programs at the time, the state of Mato Grosso attempted to implement its own colonization program, conducting both directed and spontaneous colonization – something it had started as early as the mid-nineteenth century. Indeed, two elements are central to how the "empty spaces" (in the words of federal government leaders) of Brazil were gradually subjected to colonization by Brazilian states. The first significant change was the 1850 *Lei Imperial das Terras* (Imperial Land Law) that regulated the spontaneous

[50] At the time, Mato Grosso and Mato Grosso do Sul are part of a same state called "Mato Grosso." The division in two distinct parts, the North and the South, will occur only in 1977.

[51] This expedition included members of the Indigenous Protection Service (Serviço de Proteção do Indio - SPI) and the famous Villas-Boas brothers who will prove instrumental in the promotion of indigenous tribes and the creation of the Xingu Indigenous Park (*Parque Indigena do Xingu – PIX*) in 1961.

occupation of public lands (such settlement is called *posse*). These public lands, or so-called *terras devolutas* (or *terras da União*) are lands which were not previously privately-incorporated when Brazil was a colony of the Portuguese Crown, and whose ownership was passed to the Brazilian Empire at the independence in 1822. With the 1850 law regulating *posse*, any private party (called *posseiros*) could spontaneously settle on previously-unoccupied public land under certain land size limitations and length of occupancy conditions. The second significant change occurred after the creation of the Brazilian Republic when the Republic Constitution of 1891 operated the transfer of *terras devolutas* from the federal to the state governments. States were now capable of organizing the distribution of public lands and design their colonization strategy.

Following these changes, the state of Mato Grosso began implementing two models of colonization: one private and one "public." First, large landowners and elites of Mato Grosso started capturing various *terras devolutas* for their private benefit. At this time, the regulation process is initiated by a Commissioner Judge ("Juiz Commissário") and a real estate agent (who also acts as a land surveyor, is approved by the state, and defines and delineates the land i.e. *agrimensor*). The problem in this model is that individuals tended to declare an area larger than the one they effectively occupy, often claiming properties nearing 5,000 ha by colluding with the judge and *agrimensor* (Moreno 1999). Given the widespread corruption and clientelism of land allocation, the state ended the role of the Judge in 1897. However, corruption remained at about the same scale because the governor himself sometimes validated corrupt schemes in order to increase state revenues from the land sales.

Second, the state of Mato Grosso welcomed the installation of *posseiros* donating land 'for free' to either nationals or foreigners, because it served the geopolitical purpose of settling unoccupied lands in national security-sensitive areas such as borders (Rivière d'Arc 1977). It generally distributed lots comprising 50 ha for agriculture or 200ha for pastures. Despite state efforts to promote colonization within Brazil and abroad, less than 1% of claimed areas were regulated between 1889 and 1930 (Moreno 1999). Little colonization resulted from either colonization strategies of the Mato Grosso state.

The colonization of the Araguaia Valley (starting in the 1940s after the Roncador-Xingu expedition) exemplifies the deep roots of spontaneous colonization triggered by such state policies. As a result of the expedition, colonization in this area began in 1945. Colonizers from Minas Gerais and Goiás took control of areas of *terras devolutas* along the course of the Araguaia river for cattle-ranching activities (A. U. de Oliveira 2005). They started cultivating rice, manioc, beans and maize, and even attempted to grow coffee. Later, the situation of the *posseiros* of the Araguaia Valley would evolve with the subsequent changes in colonization policy as priority shifted to private-led capitalist colonization (Rivière d'Arc and Apestéguy 1978).

The arrival of Getúlio Vargas (1930-1945) helped prompt a new colonization movement based on small properties. He also modified the federal land allocation system to limit abuses (e.g. people making too many demands for lands, etc.). With the end of the Vargas' *Estado Novo* in 1945 and the return of democracy with a new constitution in 1946, state governments started prioritizing the sale of *terras devolutas*, while maintaining colonization projects and, to a lesser extent, the tenure

regularization of existing land. In 1949, Mato Grosso created the new State Land Code[52] (*Código de Terras do Estado*) (hereafter "Code") to accelerate land privatization and regularize actual dominions under its new Land and Colonization Department (Departamento de Terras e Colonização – DTC, created in 1946). At the same time, the state allowed for the spontaneous colonization of 25 ha land plots by *posseiros* who would be granted a land title if they could prove 10 years of permanent occupation.

In 1951, the Code was amended to include flexible legal conditions for the appropriation of land. This opened a period (1950-1964) where land was sold "indiscriminately" and used as a way to settle political disputes as a reward or political favor (Moreno 1999). Because the officials in charge of state land concessions received a commission at each sale, the allocation of land sharply accelerated with the sale of lots varying from 3 to 10,000 ha. In 1950, the southern area of Mato Grosso[53] was most affected by these sales and in 1955, the northern area of Mato Grosso above the 15th parallel (above Cuiabá and Rondonópolis) became the new frontier of land allocation. Every year, the rate at which land was sold would accelerate, from a few hundred thousand hectares in the early 1950s to quantities overcoming a million in the 1960s. Based on official records, Rivière d'Arc (1977) reports that in May 1960, the state of Mato Grosso sold 1,918,334 ha in the northern area, totaling 2,032,720ha in the whole state. Furthermore, intense speculation developed as new landowners would quickly sell their plots to other buyers (without even visiting their land) and benefit from a significant premium.

[52] Law n°336 of December 6, 1949
[53] Corresponding to the actual state of Mato Grosso do Sul and the southern part of the actual state of Mato Grosso

In terms of directed colonization, the state of Mato Grosso created a colonization corporation in Fátima de Sao Lourenço to distribute lands in a settlement of 70,000 ha in the south of the state. Another example of directed colonization is in 1956: the *Colonizadora Noroeste Mato-Grossense S/A* (CONOMALI) obtained 240,000 ha of lands from the state near the Arinos river, in Northern Mato Grosso, and was authorized to allocate them to colonizers from the South of Brazil. This colonization corporation, like many others later, brought *sulistas* (i.e. colonizers from southern Brazil) from the states of Santa Catarina (SC) and Rio Grande do Sul (RS). They were almost exclusively small peasants of German origin and were invited to start coffee and rubber plantations in Mato Grosso. With very limited infrastructures (colonizers arrived and settled by the river, which was the easiest way to access this remote area of Mato Grosso), the project had limited success, and suffered from bloody encounters between colonizers and local indigenous tribes defending their encroached territory (A. U. de Oliveira 2005). Nonetheless, the model of a colonization corporation exemplified by CONOMALI later evolved to involve farmer cooperatives from the South of Brazil and set the standard for future colonization projects in the region.

The corruption and speculation prevailing in 1955-1965 eventually led to the closing of the DTC in 1966. DTC's closing at a time when Brazil wanted to favor national and international large-scale investments in land in the Amazon region paradoxically favored even more speculation, creating the phenomenon of "flying titles" which were registered in Land Registry Offices (Cartórios de Registro de Imóveis - CRIs). Flying titles lead to situations where a single area could have multiple claims overlapping one another. The state resorted to CRIs to clarify the land tenure, but this period contributed to flaw more severely the land tenure matrix of the state, fostering land

concentration in the hands of elites and the outbreak of conflicts between competing land claims. This period was best summarized by a popular saying used at the time to describe areas on which overlapping land claims existed: "*terras de dois ou três andares*" (Literally translating into "land of two or three floors") (Foweraker 1981).

One can see that by the time the military regime rose to power in Brazil, both federal- and state-level initiatives had only a limited impact on the colonization of the Amazon. Tenure uncertainty weakened the power of local elites that controlled the land allocation process, and ultimately permitted the imposition of federal programs that intended to develop the Amazon. One can however see the emergence of a colonization model relying on colonization companies (*colonizadoras*) acting as facilitators between the state land allocation system and the recruitment of migrants from various regions of Brazil. The most notable advance of the period, the building of road infrastructures, started to significantly alter the pattern of migrations to the Legal Amazon. The construction in the 1950s of the Brasília-Belém highway (completed in 1960) and the Brasília-Cuiabá highway opened up new avenues for South-North migrations. From this moment on, and with the following roads built in the 1960s and 1970s, the colonization of these areas would organize around roads rather than waterways (Becker 2005; Droulers 2004).

1.2. MILITARY REGIME'S COLONIZATION PROJECT (>1964): THE DOMINANCE OF PRIVATE-LED COLONIZATION OVER PUBLIC-LED COLONIZATION

The majority of colonization projects in the Legal Amazon at the beginning of the 1960s was based on low-intensity cattle-ranching (generally only 1-2 heads per ha). Very often, the true intention behind most colonizers and colonization corporations was simply to take hold of the land for speculation purposes. This logic was both perpetuated and changed by the military dictatorship's new public policies.

The military regime's new focus on Amazon colonization paralleled the development of a concern for national security in the *Escola Superior de Guerra* (Superior War College) initiated partly by the influence of the military cooperation between Brazil and the U.S. since World War II. As noted by Oliveira (2005: 69), the intent of the regime was to further industrialize and modernize agriculture in the Center-South, while also tackling sub-development in the Northeast and occupying the Amazon. The military regime viewed the Amazon as an empty space (with complete disdain/ignorance for indigenous and local populations) that should rapidly be secured to avoid any disputes over international borders, the political and economic centers of neighboring countries being much closer to the forest than the ones in Brazil. A second and not understated objective of the Amazon colonization was to ease rising rural conflicts both in the Northeast (where land concentration was historically high) and the South (where land concentration was increasing due to the modernization and mechanization of agriculture). As such, the colonization of new areas by colonizers from either the Northeast or the South was always an 'safety valve' avoiding successive governments to conduct an actual land reform in their places of origin.

1.2.1. The *Operação Amazônia* and the SUDAM phase (1964-1970): reinforcement of fiscal incentives to occupy the Amazon

Various authors delineates the colonization policy of the military regime in three distinct phases (e.g. Campari 2005; Mahar 1979). In a first phase (1964-1970), the government launched the "Operation Amazônia" (*Operação Amazônia*) in 1966[54] to reform the main institutions supporting the colonization of the Legal Amazon. Recognizing the importance of modernizing the institutions supporting colonization, the government transformed the SPVEA into the Superintendence for the Development of the Amazon (*Superintendência do Desenvolvimento da Amazônia* – SUDAM). Citing official documentation, Stella (2009) reports that the goal of the SUDAM was to fund all the infrastructures necessary to support the *Operação Amazônia* by funding projects in the transport (roads, ports, airports), electrical, telecommunications, and health sectors, although some authors argue that these plans did not mention any specific infrastructures and remained vague (Mahar 1979). To support the SUDAM, the military government transformed the old *Banco da Borracha* (Rubber bank) that served the rubber extraction boom at the turn of the 20th century into the *Banco da Amazônia S.A.* (Bank of Amazônia - BASA).[55]

Importantly, the military did not invent a completely new funding model to increase capital in the Amazon region. It modelled the SUDAM following the successful example of the Superintendence for the Development of the Northeast (*Superintendência do Desenvolvimento do Nordeste* – SUDENE) created in 1959[56] under the government of President Kubitschek to support

[54] Law n°5.173 of October 27, 1966

[55] The government did not transform the Rubber Bank itself since it had already been transformed into the Credit Bank of the Amazon (*Banco de Crédito da Amazônia* – BCA) in 1950 to help finance agricultural and industrial projects of the SPVEA (Mahar 1979). Hence the government transformed the BCA into the BASA, the former being the legacy of the Rubber Bank.

[56] Law n°3.692 of 1959

implemented import-substitution industrialization in this region. The funding model of this institution (developed in 1961[57]) relied on the creation of fiscal incentives to support investment projects and relied on combined foreign and national capital (Mahar 1979).

Following this model, the SUDAM offered companies located in the Amazon region the possibility of a tax exemption of 50% to 100% (depending on a company's date of installation in the Amazon) if they purchased land and invested in agricultural projects in the Legal Amazon.[58] Furthermore, it created tax exemptions on inputs (such as transports costs, machine purchases, etc.) and outputs (e.g. export of timber) facilitating business operations and effectively lowering the price of capital in the region (Hecht 1985a). Other fundamental mechanism to attract capital from outside Amazonia to the region, the SUDAM offered Brazilian companies[59] up to 50% tax credit it they funded projects in the Amazon. In practice, companies could choose to spend this tax credit on a list of SUDAM-approved projects or their own project (provided that it had been improved by SUDAM). Funds would be earmarked in a bank account of BASA which would spend the funds on SUDAM-approved projects using the Private Investment Fund for Amazon Development (*Fundo Para Investimentos Privados no Desenvolvimento da Amazônia* – FIDAM). In return, companies would receive non-voting shares in the firms receiving the tax credit money (Mahar 1979). In addition to these incentives, Binswanger (1991) states that, at the time, agricultural activities were virtually exempted from taxes since several provisions in the tax code

[57] This system had already been expanded to the Amazon region by the SPVEA as early as 1963 by law 4,216 of May 6, 1963 (Mahar 1979; Le Tourneau unpublished).

[58] Art. 1, Law 5.174 of October 27, 1966. The law states that firms which are already in the Amazon at the by the publication of the law will get a 50% tax exemption, while those who either have not started operations yet or will be installed before the end of the 1971 fiscal year will get 100%.

[59] Located outside the Amazon

allowed up to 80-90% of profits be discounted from the taxable income. This large tax exemption apparatus provided business projects in the Amazon with a very welcoming fiscal environment.

The scope of application of SUDAM's incentives was the Legal Amazon which, at the time, started with all the area above the 16th parallel in Mato Grosso. Of all SUDAM's projects, 43% in 1970 and 38.9% in 1980 were directed toward agricultural-ranching sector (Stella 2009: 156). Another 42% (approximately) of the projects were dedicated to the development of industry across that period, demonstrating the importance of SUDAM's funding in the development of Manaus. This sector-based funds distribution however hides the fact a very sizeable part of the funds were initially projected to go toward the creation of infrastructures. The transport sector represented 40.5% of the first Five-Year Plan of the SUDAM and 50.8% of the first Amazon Development Plan (1972-1974) (Mahar 1979). However, according to Mahar, these plans "fell far below expectations" (Mahar 1979:14). It is important to note that Mato Grosso was not the prime destination of this funding, receiving only 31.1% in 1970 and 23% in 1980 in second after Pará (receiving 33.1% and 42.6% respectively) and before Amazonas (receiving 17.9% and 21.8% respectively) (Stella 2009: 157). However, Mato Grosso benefitted (at least in the through mid-1976) of 61.2% of all funds affected to livestock projects, concentrated for their major part in northern Mato Grosso (Mahar 1979: 102).

Campari (2005) considers this period a failure because: (1) cattle-ranching became just a way to capture large government subsidies; and (2) land in the Amazon became a commodity as a result of intense speculation, resulting in land values disconnected from the reality of land-use. Many were the entrepreneurs who, besides the possible returns on investment in cattle-ranching,

agriculture, or mining activities, were simply looking to purchase land as a reserve of value against inflation. A good part of SUDAM funds would be diverted and disappeared by the phenomenon of "ghost ranches," which produced literally nothing and existed for the sole purpose of capturing federal subsidies and land value (Campari 2005). This corporate-dominated phase of colonization policies benefitted the elite and large-corporate groups, and did little to effectively colonize the Amazon at a large scale.

1.2.2. The National Integration Plan phase (1970-1980): the promotion of agricultural projects

In the second phase (beginning in 1970), the government started the National Integration Plan[60] (*Plano de Integração Nacional – PIN*) and marked a turn toward agricultural projects and the social dimensions of Amazon colonization. The objective of the PIN was to develop road infrastructure to encourage migration away from the Northeast and the South. According to Mahar (Mahar 1979), President Médici would have been marked by a visit in the Northeast in early June 1970, which had just experienced a severe drought. This inspired him to create with this plan a large highway connecting the Northeast to the Amazon as a way to relieve the ongoing tragedy there: the TransAmazon highway. Along with the PIN, the government launched the Land Redistribution Program[61] (PROTERRA) program to redistribute land in the Amazon region to small-scale colonizers. The moto at the time was "manless land for landless men" (*Terra sem homens para homens sem terra*). This way the government hope to remedy the very unequal distribution of land in the Northeast by operating large transfers of landholdings to the private

[60] Decree-Law n°1.106 of June 16, 1970
[61] Decree-Law n°1.178 of June 1, 1971

sector which would then be resold (or offered through official colonization programs) as small and medium land lots to colonizers.

To conduct this policy, the federal government nonetheless needed to take back control over the land. In 1971,[62] the federal government operated a large transfer of land from the state- to the federal-level by nationalizing all land situated within a 100-km buffer around all pre-existing or projected federal highways in the Legal Amazon. This policy change allowed the federal government to effectively take back a good share of the land transferred to the states in 1891. A year earlier, the federal government created the National Institute for Colonization and Agrarian Reform[63] (*Instituto Nacional de Colonização e da Reforama Agraría* – INCRA) and charged it with helping small-scale farmers to settle on 100ha land lots in the Amazon (of which they would have to preserve 50% under forests). INCRA was also charged with providing the farmers with all the support needed: temporary land title, credit, seeds, health and education services, etc. Due to the absence of a rural cadaster, this redistribution of land encroached upon previous state and current federal tenure policies, and instigated sharp conflicts with other organizations like SUDAM (created previously under the older paradigm of favoring large-scale entrepreneurial projects).

Despite also being fully included in the Center-West region of Brazil, Mato Grosso benefitted from large federal programs other than the SUDAM, especially in the 1970s (during the second phase). In 1967, around the same time as SUDAM, the federal government created the Superintendence for the Development of the Center-West[64] region (*Superintendência do*

[62] Decree-Law n°1.164 of April 1, 1971
[63] Decree n°1.110 of July 9, 1970
[64] Law n°5.365 of December 1, 1967

Desenvolvimento do Centro-Oeste – SUDECO) by absorbing the former Central Brazil Foundation (Fundação Brasil Central - FBC). Its primary goal was to ensure the integration of the Center-West with the South through supporting the construction of roads, as well as maintaining schools and hospitals. Unlike the SUDAM and the SUDENE, the main budget of the SUDECO depended on federal investment choices and lacked an incentive system based on tax exemptions (S. de Abreu 2016).

In the mid 1970s, the SUDECO administered two programs important to the development of Mato Grosso's agriculture: the POLAMAZÔNIA (jointly with SUDAM) and the POLOCENTRO programs. The POLAMAZÔNIA program (*Pólos Agropecuários e Agrominerais da Amazônia*) was created in 1974[65] to support the development of agricultural and ranching activities in the Amazon region. In Mato Grosso only 3 areas benefitted from the program (Aripuaña, Juruena, and the Xingu/Araguaia area) through support to "pioneering agricultural entrepreneurialism" (Abreu 2016: 129). In practice, the SUDAM controlled the money while the SUDECO was in charge of planning and feasibility studies as well as monitoring projects. In 1975, the POLOCENTRO program (Programa de Desenvolvimento dos Cerrados) was created[66] to support the agricultural development of over 3.7m ha in the Cerrado region (in Mato Grosso and Goias). Unlike other programs, it was principally aimed at providing research and the technological packages (including large-scale investments such as the construction of crop storage facilities and the opening of local limestone quarries) necessary to turn the low-fertility soils of the Cerrado into highly productive ones. This support greatly facilitated farmers' access to rural credit for machines and critical inputs (such as lime to correct soil acidity). The hope of the program was that the dynamism of the

[65] Decree n°74.607 of September 25, 1974
[66] Decree n°75.320 on January 24, 1975

subsidized areas would eventually spread to surrounding areas.[67] One of the areas of concentrated investments was the Parecis plateau, where the SUDECO created crop storage units in Diamantino, Tangará da Serra, and in Parecis. The program was firmly committed to support modern large-scale farming as the average farm size benefitting from POLOCENTRO is 998 ha, with 76.45% of credit going to farms larger than 500 ha (Abreu 2016: 171 & 191).

The second phase of public colonization triggered mass migration to the state of Pará, attracting small peasants from the northeast settling around the TransAmazon highway (built in 1970) in the regions of Santarém and Altamira. The second phase also attracted small holders from the south of Brazil to the state of Rondônia, multiplying the total state population by 4 in ten years (1970-1980) (Théry 1996). In Mato Grosso, only two sites were subject to this type of colonization. The first was in Guarantã do Norte, and the second in Lucas do Rio Verde.[68] From 1970 to 1975, INCRA could not control the massive migration flow coming from the Northeast and could not "*cope with the demand for demarcation of individual plots, recording claims, formal surveying, titling, and provision of other promised services and inputs such as infrastructure, education, health care, seeds, and fertilizers*" necessary to the success of public colonization projects (Campari 2005: 35).

[67] See the work of Abreu in which she cites and official communication of the SUDECO at a conference: " (…) The program really ambitions to recuperate or expand the agricultural frontier. These areas, then, will serve as development hubs, in such a way that they will radiate in other neighboring regions an already-advanced agriculture" (Abreu 2016: 148)

[68] The project of Lucas was however implemented in 1981-1982, so later than the one in Guarantã do Norte

1.2.3. The eruption of colonizadoras in Mato Grosso

During that same period, the state of Mato Grosso approved 36 private colonization projects which consisted of transferring a large extent of land (hundreds of hectares) to *colonizadoras* usually founded by a few wealthy individuals from the South of Brazil (A. U. de Oliveira 2005). The official objective of the *colonizadoras* was to organize recruitment of colonizers from Southern states (RS, SC, PR), and convince them to buy land lots of size varying between 100 and 500 ha to start agricultural or ranching activities in the new frontier. These projects were made possible because of the new infrastructures constructed by the military regime under the PIN (in particular the Cuiabá-Santarém highway (BR-163) finished in 1975 and the Cuiabá-Porto Velho highway (BR-364) built in 1964 but not paved until 1982). Today, most cities of Center-North and Northern Mato Grosso are the legacy of those giant colonization projects as some turned into regional capitals, such as Sinop or Alta Floresta. An overwhelming part of these projects were located in forested areas of Northern MT, but a few were located in the Amazon-Cerrado transition areas (e.g. Nova Mutum, Sorriso). The area of land covered by such projects could be as low as 100,000 ha and as high as 1 million ha.

If cattle-ranching was the dominant project, one can denote other strategies of colonization based on extraction (e.g. rubber, timber, or gold). To give but a few examples, the CONOMALI (cited above) and the INCOL (Imovéis e Colonizadora Ltda) promoted establishing plantations of rubber or coffee to colonize the area. The CONOMALI resulted in the founding of the municipalities of Juara and Novo Horizonte, while the INCOL influenced the creation of Sao José do Rio Claro, Nova Maringá and Brianorte. Other projects were based on cattle-ranching and rice cultivation or were sometimes based on a risky strategy combining diverse production systems. For instance, the

COLONIZADORA SINOP created 4 municipalities in a land lot ("gleba") of 650,000 ha (Sinop, Vera, Santa Carmem, and Cláudia) and tried different activities. First, they tried coffee, then guarana, and finally, they got funding from the SUDAM to install a mandioca processing factory. Because the labor was costly, the factory never became profitable and colonizers turned toward cattle-ranching and timber extraction to sustain their livelihoods until eventually converting to soybean cultivation in the late 1990s (ITW n°053).

These *colonizadoras* were almost always led by large entrepreneurs from the South (Dubreuil et al. 2009). The *colonizadora* in Sinop was founded by Ênio Pepino, an entrepreneur that had already created the municipality of Maringá, in the southern State of Paraná, and successfully settled colonizers there. This history partly explains why these *colonizadoras* were bringing colonizers from the South to Mato Grosso: these corporations were opening "recruitment offices" in the cities in which they had an influence or networks of farmers. This reflected the voluntary bias of the government, since the *March to the West*, to promote colonization by white, European-descent farmers from the South who were assessed (by the government) as being more entrepreneurial than their fellow citizens (Abreu 2015). Along with the many *colonizadora* offices popping up in the South in the 1970s and 1980s, other individuals were "freelance" real estate agents selling land in Mato Grosso, usually mere *posse* over public lands to small farmers with much less guarantee of tenure security. *Colonizadora* projects, however, did not necessarily always provide land tenure security for the colonizers, who were sometimes surprised to find that they were only given the "promise" of a land title by the *colonizadora*. It could be that the *colonizadoras* sometimes had both an area legally donated by the state and an additional area illegally appropriated around it, or that they had sold the same area twice to different colonizers. As Oliveira reports, the

COLONIZADORA LÍDER (municipalities of Colíder and Nova Canaã) took control of an area by appropriating (*grilando*) federal lands and selling them to colonists from the South. In the 1970s, everyone realized that the land had been illegally appropriated. And in 1982, the INCRA expropriated the whole city to conduct land reform, compensating the previous settlers with more land outside the official colonization area [ITW n°018] (VanWey et al. 2013). On shaky tenure grounds, a large market of illegal trade of rights to *posse* started developing on the reformed land lots.

This type of private-led colonization had mixed results in northern Mato Grosso, as the initial goal of the project was diverted by the founders or the settlers given the implacable reality of the local economy. For instance, the INDECO (Integraçao, Desenvolvimento e Colonizaçao), founded by entrepreneur Ariosto da Riva acquired 900,000 ha (some of which illegally) between 1971 and 1973 in the *gleba* Raposo Tavares (municipalities of Alta Floresta, Paranaíta, and Apiacás). His initial intention was to settle people through agriculture. In practice, however, this area developed through the sale of timber and gold mining activities conducted by *garimpeiros* against the *colonizadora's* will. Similarly, the OMETTO group purchased 250,000ha north of the state and created the Matupá colonization project and slowly turned into a gold mining town marked by social conflicts and violence. Overall these colonization projects do not reflect a continuous and gradual advancing colonization frontier, but a colonization by "jumps" with settlements isolated from one another by dense forests (Rivière d'Arc 1977). Furthermore, Dubreuil et al. (2009) remarks that in spite of being spearheaded by the state of Mato Grosso, the colonization frontier based on the model of the *colonizadora* was in fact directed and supervised remotely from the South of Brazil.

1.2.4. The decline of the military regime and the end of colonization incentives (1980s)

The third and final phase (1980s) corresponds to the decline of the military regime and the generalized economic crisis named "década perdida" (the lost decade) in Brazil. The last development program to exist before this phase was the POLONOROESTE[69] (*Programa Integrado de Desenvolvimento do Noroeste do Brasil*). Launched under the government of President Figueiredo, the POLONOROESTE permitted the paving of the Cuiabá-Porto Velho highway (BR-364), thanks partly to the funding of one third of the program by the World Bank (S. de Abreu 2016). However, in a context of hyper-inflation, re-democratization in Brazil and economic difficulties resulted in the decrease and eventual suppression of federal subsidies to colonization and rural credit to agriculture.

Nevertheless, the times became more difficult for agricultural activities: after benefitting from income tax exemptions until the late 1980s, agricultural activities started to be taxed and started generating revenue for the state. Nonetheless, Campari notes that "intraregional migrations and forest clearing did not correspondingly decline during the 1980s. This suggests that Amazonian migrations and deforestation during the late-1980s responded to intra-frontier forces different from those of the 1970s" (Campari 2005: 39). The colonization of Mato Grosso indeed did not decline during the 1980s, demonstrating that the new frontier obeyed to a logic which was not fully dictated by macro-economic conditions of world markets and state subsidies. As I explore in Chapter 2, this had different implications in terms of forest clearing for the state of Mato Grosso,

[69] Decree n°86.029 of May 27, 1981

as land clearing was maintained in areas of dynamic agricultural projects and diminished in colonization areas highly dependent upon state subsidies.

2. THE COLONIZATION OF THE AMAZON-CERRADO TRANSITION AREAS: SIMILARITIES AND DISTINCTIVENESS WITH MAINSTREAM COLONIZATION IN MATO GROSSO

To a large extent, the mainstream Amazon colonization narrative does not explain why the settlement projects located in the Amazon-Cerrado transition areas of the BR-163 and the Chapada dos Parecis ultimately resulted in lasting and economically successful agricultural production. Most private-led colonization projects in forested areas of Northern Mato Grosso did not result in economies as stable as those conducted in the Cerrado. The key difference is that only the projects located in the Amazon-Cerrado transition areas were organized around agriculture from the start (and held on to it). This, however, does not explain entirely the reasons behind the success of this strategy and why modern agriculture was able to fully adapt to the difficult conditions existing in this area.

2.1. THE ALTO TELES PIRES (BR-163) AND THE CHAPADA DOS PARECIS: A BRIEF DESCRIPTION

Prior to the construction of the BR-163 and the BR-364 highways, the Alto Teles Pires and Chapada dos Parecis areas were sparsely occupied by indigenous tribes and a few garimpeiros and colonizers around rivers (Coy and Klingler 2014). It was the territory of numerous indigenous tribes such as the Nambikwara, Paresí, Bakairí, Kayabí, Suiá (**See Figure 1.1**). The BR-163 was initiated by the 8th and 9th *Batalhão de Engenharia e Contrução do Exército* (8th and 9th Battalion of the Army Corps of Engineers) on September 3, 1970. Following the account made by José Mereilles (as reported in Oliveira 2005: 78), who was one of the leaders of the operation, one of

the goals was to finally integrate a very large portion of Mato Grosso to the rest of the economy and the country. Once completed, the road would connect the geographic center of the region (Colíder) to the port of Santos in Sao Paulo by a distance of 3000 km and to the port of Santarém by 700km. The project took 6 years to be completed: 1971 was busy with topographic work, 1972 saw the first equipment arrive, and in 1976, the highway was finally inaugurated. Importantly, the road was simply laid out as a dirt road but not paved until much later (only partially), which created enormous travel difficulties especially during the rainy season as trucks and pick-ups often got stuck in the mud.

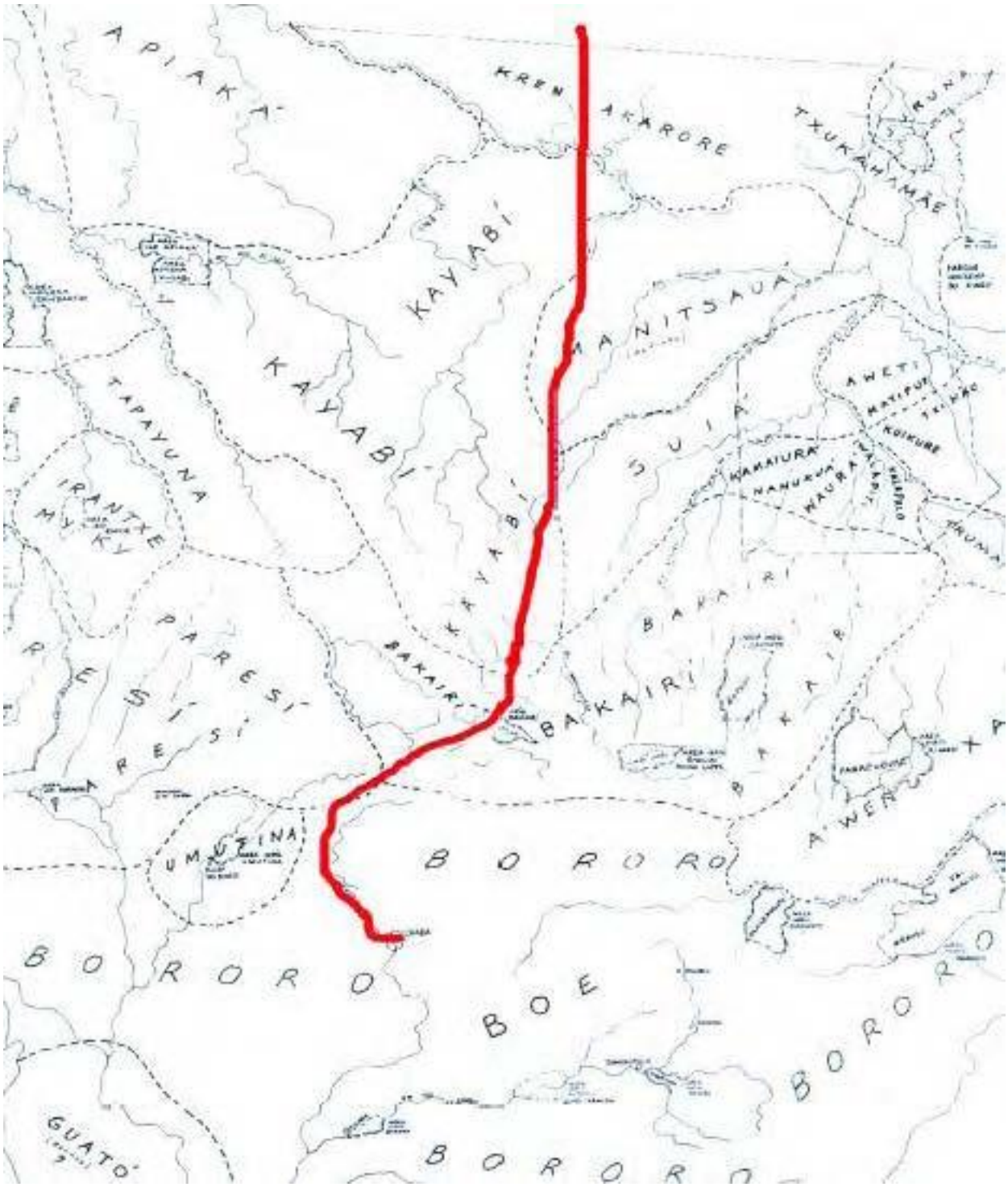


Figure 1.1. Original indigenous territories in Mato Grosso. The red line represents the BR-163 highway. **Source**: Oliveira 2005: 75

The creation of the BR-163 attracted an increasing number of migrants, given that the state of Mato Grosso was also the simultaneous receiver of 4 different development programs:

PolAmazonia, Polocentro, Polonoroeste, and Prodeagro. Oliveira notes that between 1970 and 1980, 456,000 people came to MT, 57% of migrants originating from the Center-South area, especially from Paraná. The arrival of migrants coming from the South dramatically increased the competition for land in northern MT, encroaching upon indigenous lands and leading to sharp conflicts with them, some authors speak of this time as a real "genocide" (Oliveira 2005: 84).

Due to the strength of SUDAM's incentives, most of the migration inflow at the time (1960s & 1970s) was concentrated in forested areas of northern MT, from Sinop and onwards as well as on the other side of the Xingu Indigenous Park, in eastern MT. Migrants from the South of Brazil heading toward these areas hoped that cattle-ranching would be easier because the forest-covered soils were thought to be more fertile. Others went to pursue timber extraction activities which they had initiated in the forests of Western Paraná. The key point here is that migrants going to northern MT did not go there to start crop cultivation. On the contrary, migrants, cooperatives, and *colonizadoras* settling in the Amazon-Cerrado transition area south of Sinop were hoping to turn these areas into prosperous agricultural land. As the marketing material of the *colonizadoras* at the time demonstrated (**See Figure 1.2**), the first pioneers settling down in the region hoped to cultivate rice, as this was perhaps the only crop that could be grown on such acidic soils. However, after two or three years, yields were dropping, and land had to be abandoned. The colonization of these areas was thus quite uncertain, as few believed in the real agricultural potential of that region. Some of those individuals headed colonization firms, such as José Aparecido Ribeiro of the Colonizadora Mutum. This southerner helped settle numerous families along the BR-163 highway in the 1970s with a vision for agriculture that included the founding of the city of Nova Mutum.

Most colonizadoras along the BR-163 shared the project to create new urban settlements and thus provided with space for a city.

The story unfolded differently in the Chapada dos Parecis region, which was colonized later. The municipalities of the study area (Campo Novo do Parecis, Sapezal, Campos de Júlio) were little explored until their colonization in the mid-1980s and the creation of the Tangará-Campo Novo do Parecis MT-170 state road. South from there, the municipality of Tangará da Serra already counted with coffee plantations since the mid 1950s and later on converted to cattle-ranching activities (Dubreuil, Bariou, Passos, et al. 2005). A city was founded there in the 1960s by a colonizadora (the Colonizadora Sita – *Sociedade Imobiliária Tupã para agricultura*) led by two individuals. Campo Novo do Parecis started developing only after a few pioneers settled there in the late 1970s, arriving on a plateau that had not been subject to any modern agricultural use (including ranching) until then. Contrary to the BR-163 story, the area was not colonized by *colonizadoras* in the traditional sense (See Chapter 2). Rather, it was the result of a few individuals bringing colonizers from the South and distributing immense areas of land, but they had no plans of building cities and infrastructures for the colonizers. The building of the city of Campo Novo in the 1980s, for instance, is due to land donations by three of the first families settling in the area. As remarked by historian João Lucidio, the municipality of Sapezal was not colonized by André Maggi,[70] as the popular story is told (Lucidio 2017). Maggi is rightly remembered for founding the city of Sapezal and being instrumental in the provision of infrastructures (i.e. electricity, schools, etc.). However, the area had initially been colonized by southern farmers brought here by

[70] Founder of the Brazilian soybean production and trading firm AMAGGI, father of Blairo Maggi (former Agriculture Minister of Brazil under the government of Michel Temer). It is Blairo Maggi and his brother (Itamar) who found the first farm that André Maggi bought in Sapezal (Lucidio 2017)

a few individuals grouped into a colonizadora called Joaçaba. Rather than a colonizadora, it was a group of individuals distributing land to colonizers, a key distinction with the BR-163. This happened too in Campos de Júlio which land was distributed by a handful of individuals (including the Masutti family). The development of agriculture on this plateau show well how the "vision" for agriculture of the colonizadora projects of the BR-163 was not something only shared by an elite of settlers, but rather shared by all colonizers arriving in these areas, as the example of the Chapada dos Parecis illustrate. Producers from Campo Novo do Parecis were particularly entrepreneurial, as they associated themselves to create a sugarcane cooperative as early as 1980 in the area (the Coprodia), still one of the only sugarcane cooperatives in the area to this day.

The study area thus presents distinct colonization story (further examined in this dissertation through the stories of colonizers, in Chapter 2), in which the model of the colonizadora alone does not explain why areas were colonized. The BR-163 highway area presents more the traditional model in which a colonization firm establishes a city (with infrastructure provision) and distribute land around it whereas the Chapada dos Parecis area presents a more complex story in which colonization firms (in the traditional sense) were absent, leaving much of the agricultural development to the individual initiatives of southern colonizers. Before further discussing how these differences may have affected the colonization history of the study area, it is however necessary to explain how soybean agriculture took off in the area, since most farmers had the time faced numerous difficulties in making money with rice cultivation.

Figure 1.2. Marketing poster inviting southern farmers to migrate to Cerrado areas of MT, from the *colonizadora "Tropical – Colonização e Melhoramentos Tropicais Ltda"* which colonized areas beyond the area of the *colonizadora Mutum* in Nova Mutum, MT. Picture taken by the author

2.2. The revolution in Cerrado agriculture: U.S.-Brazil agronomic cooperation, soybeans, and favorable international market conditions

Several innovations in Cerrado agriculture happening in the 1960s and 1970s did save the prospects of agriculture in this area, however. The concern for and history of the Amazon sometimes obscure the fact that the Cerrado had long before been set on an agricultural development trajectory that would later spill over into the Amazon. Until the 1950s, the Cerrado had not yet been subject to much agricultural development because of the priority given to sugarcane and coffee plantations in coastal areas. The state presence was only remotely felt and the region presented few infrastructures conducive to development. Cerrado soils were considered too poor for large-scale commodity production despite a few positive local experiences in improving fertility.

When Brazil invited researchers to evaluate the potential location of the new capital, Brasília, it attempted to evaluate all aspects of this location, including possibilities of colonization. Among the researchers invited, the French geographer Francis Ruellan relates how the work was divided in several teams assessing the topography, climate, hydrography, economic questions and colonization potential of different sites (Ruellan 1948). As part of this team, Reeshon Feuer of Cornell University was invited to Brazil in 1954 to assess the soil fertility of various Cerrado locations and concluded that improvement could only be possible through adoption of powerful chemical fertilizers similar to those developed by the U.S. (Nehring 2016).

This possible agricultural trajectory had been anticipated by another prominent American who was influential in the transformation of the Cerrado: Nelson Rockefeller. Franklin Roosevelt, who

had visited Brazil and the Cerrado in 1913-1914 told Rockefeller that the Cerrado would be one of the most important areas of development in the world. Rockefeller had even acquired a farm of 120,000 acres (about 48,000 ha) in Mato Grosso do Sul in the 1950s. Through the American International Association for Social and Economic Development (AIA) and the International Basic Economy Corporation (IBEC), both of which he founded in 1946 and 1947 respectively with the intention to spread American capitalist institutions across the world, Rockefeller contributed significantly to advances in Cerrado agriculture. Specifically, he founded the IBEC Research Institute (IRI) with the main purpose of "export[ing] U.S. agronomic expertise" (Nehring 2016: 209), and created field stations in São Paulo and Goiás where scientists of IRI and the Campinas Agronomic Institute (*Instituto Agronomico de Campinas* – IAC) started working on the response of Cerrado soils to phosphorus and sulfur when planting corn, cotton, and soybeans. These researchers found that aluminum toxicity was very high in Cerrado soils and thus concluded at the turn of the 1950s-1960s that adding lime and phosphates would correct the soil fertility and allow for intensive agriculture to take place.

From this moment on, and especially after the 1964 military coup, the joint Brazil-U.S. commission for economic development envisioned the Cerrado as a modern agricultural frontier based on the 5 most profitable commodities: soybean, rice, beans, corn, and cattle. The United States Agency for International Development (USAID), partly seeing this as an extraordinary opportunity for U.S. fertilizer export interests, supported the training of Brazilian scientists and funded numerous surveys to improve agricultural knowledge about the Cerrado, spending as much as US $100 million between 1961 and 1969 (Nehring 2016: 213). Of the five commodities tested at the time, soybeans stood out as the favorite because of its nitrogen-fixing properties (an

important asset given the low nitrogen content of Cerrado soils). Additionally, soybeans had an important commercial potential, as it could serve as a processing element (e.g. oil) in many industrial foods or products. The Brazilian government saw the export of soybeans as a means to improve the country's balance of payments. However, Nehring points out that two key events were necessary for such a strategy to succeed: "soybeans didn't spread widely until international market opportunities and scientific work successfully adapted the plant to tropical latitudes" (Nehring 2016: 211).

Indeed, adapting soybeans to tropical conditions further north was a major technological challenge. Among these challenges, one can note acidic soils, non-adaptation of soybean varieties to the region's photoperiod, low phosphorus, low calcium, aluminum in soils toxic for plants, and so forth (Wilkinson and Sorj 1992). As remarked by Spehar, despite the Cerrado's receiving the 1500mm of rainfall required for rainfed agriculture, the distribution is erratic: "dry spells can occur during the rainy season" (Spehar 1995: 142). Drought stresses can happen in January or February which then hits the crop the hardest, in the middle of the rainy season (which spans from October to April).

To address these challenges and further develop agricultural research in the country, Brazil created the Brazilian Corporation for Agricultural Research in 1972[71] (Empresa Brasileira de Pesquisa Agropecuaria, hereafter named EMBRAPA). Building on previous research by the IRI and the Agricultural Research Center of the Cerrados (*Centro de Pesquisas Agropecuárias dos Cerrados* – CPAC, later integrated to EMBRAPA as the EMBRAPA-Cerrados), researchers at

[71] Law no 5.851 of December 7, 1972

EMBRAPA developed a soybean variety based on American and Japanese germplasms. At the end of the 1970s, the 'Doko' soybean variety developed by Dr. Plínio Itamar Mello de Souza allowed "for the soybean to flower under the limited daylight at the Cerrado's tropical latitude and also had a tolerance to low calcium nutrients and aluminum toxicity" (Nehring 2016: 214). The IAC-2 variety developed by the Campinas Agronomic Institute opened up a "genetic improvements that made possible the expansion of soybeans out of the traditional southern States into the Cerrados region and the northeast" (Wilkinson and Sorj 1992: 23).

The EMBRAPA created technological packages to expand soybean cultivation to the entire region, for instance by supporting the creation of limestone quarries, but the major contribution of the institution was about agricultural practices. All the key innovations of Cerrado soybean agriculture (planting schedules, soil treatment, management systems) were developed during this period of strong cooperation with the U.S. (Wilkinson and Sorj 1992). Among the innovations of EMBRAPA, one can note the development of biological control of pest, biological nitrogen-fixation (*rhizobium-based*) (Döbereiner 1997) that saving large amounts of input costs (up to 80%), and no till techniques (which however resulted in greater use of herbicides) (Wilkinson and Sorj 1992). Another agricultural breakthrough which would have importance for the Cerrado and the Amazon around the same time is the development by EMBRAPA of a variety of grasses imported from Africa, called *brachiaria*, that also allowed for the intensification of cattle-ranching.

At least as important as the technological factor, and probably speeding up the search of tropical-adapted soybean varieties, the government of Richard Nixon announced on June 27, 1973 restrictions to the exportation of soybeans. Referred to as the "Nixon shock," this caused soybean

prices to soar and thus gave additional incentives to the export-oriented strategy of soybean in Brazil. The Nixon shock also raised concerns from soybean-importing countries now faced with the uncertainty of catering to their internal demand. In particular, Japan sought to create new supply zones and came to Brazil to directly support the expansion of soybean cultivation, spending US $300 million on infrastructure and resettlement in the Cerrado through the Japanese International Cooperation Agency (JICA). This also resulted in the Program for Japanese-Brazilian Cooperation for the Development of the Cerrados (*Programa de Cooperação Nipo-Brasileira para o Desenvolvimento dos Cerrados* – PRODECER). Designed in 1974, the PRODECER was responsible for a large part of the transformation of Brazilian Cerrado into an agro-industrial frontier because it first brought critical infrastructures such as soybean crushing factories to some areas of the Cerrado. It did this through successive phases: the PRODECER I started in 1979 (in Minas Gerais state) and ended in 1985 while the PRODECER II (which reached the states of Minas Gerais, Goiás, Bahia, Mato Grosso and Mato Grosso do Sul) started in 1985 and ended in 1992.

As a result of these multiple technological, institutional, and market factors, the Cerrado biome represented already more than half of the soybean production in Brazil by the end of the 1990s. In this period of intense technological advancement, it is key to note the conclusion of Wilkinson and Sorj about soybean expansion: ""no straight line links market signals to research priorities. A decline in crop prices may be more important than any increase in input prices and may simply lead to crop diversification" (Wilkinson and Sorj 1992: 25). By this, the author means that regardless of soybean price fluctuations, soybean was able to expand thanks to technological innovation that saved innumerous costs, marking the success of the Brazilian model of soybean agriculture. Producers took their part in the research by leading numerous experiments on their

farms (Spehar 1995), especially in the study area. Soybean was first cultivate in the south of Mato Grosso during harvest year 1977/1978, in the Taquari district (Bonato and Bonato 1987), and they started being cultivated in the study area around 1982.

3. CONCLUSION

As a result of market, technological, and geopolitical shifts, the colonizers of the Amazon-Cerrado transition areas of the BR-163 and Chapada dos Parecis found themselves in a historically favorable set of conditions to develop crop cultivation in the Cerrado (**See Figure 1.3**). The only thing that was missing was a strong labor base to carry out the colonization. Southern colonizers thus became "the social base of cultivation in the Cerrado" (Nehring 2016: 214). Nonetheless, colonization was far from easy as the high failure rate of colonization projects can attest. In that context, the fact that the BR-163 highway and the Chapada dos Parecis areas do not present similar stories in terms of colonization firms but still managed to both become very successful soybean production areas denote that the agricultural vision for this region was simply shared by all southern colonizers arriving there. The next Chapter retraces the colonization story of migrants arriving in the Alto Teles Pires and Chapada dos Parecis regions and some of their challenges.

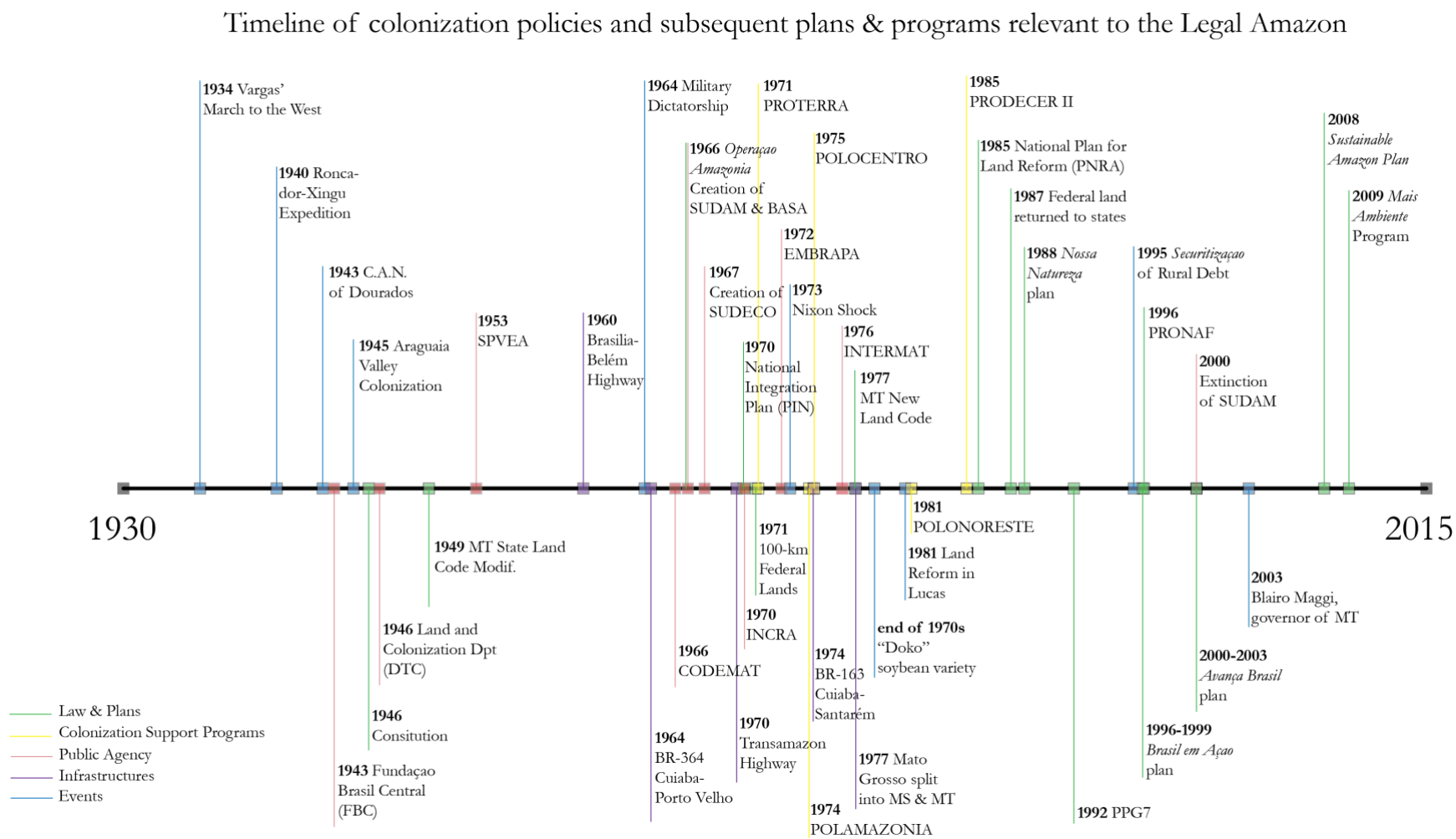


Figure 1.3. Timeline of colonization policies and relevant events in the colonization of the Legal Amazon

Chapter 2. Large-scale soybean producers of Mato Grosso

1. The colonizers of the Alto Teles Pires and Chapada dos Parecis: Trajectory and Characteristics of Large-scale Farmers in the Making

After reviewing the key "enabling" ecological, technological, and economic factors that made the agricultural colonization of the study area *possible*, it is necessary to describe *who* was able to carry it out. The conditions described in the previous section were, in a way, "available" or present to most of the Cerrado in Brazil. It is nonetheless primarily in the Alto Teles Pires and the Chapada dos Parecis that large-scale soybean agriculture boomed. This suggests that the actors colonizing the area, represented by smallholder farmers, were able to take advantage of specific socio-ecological conditions of capital, infrastructure, technology, etc. In this section, to explain why this group of farmers succeeded, I describe the key characteristics of this population through the stories of those who became large-scale soybean producers today.

1.1. Sample characteristics and representativeness

In this part, I describe the 104 soybean producers interviewed in the study. A specific caveat must be addressed at the outset: the story that follows is mostly that of those on the "winning side" of the agricultural colonization history of the BR-163 and the Chapada dos Parecis. Since the sample captures soybean producers owning or producing over 2,000 ha, the story is likely to have several biases. First, I will be unable to show the trajectories of numerous farmers who have "failed" in or have been "pushed away" from the region for a variety of reasons. Many pioneers and subsequent migrants in the region have decided to sell their land plots and move to other frontiers, giving way

to a large literature about the implications of this *lot turnover* (Campari 2005). In Mato Grosso, colonizers initially arriving in one of the two study regions may have chosen to relocate to nearby municipalities, or to other regions or states altogether. Thus, it is fairly common in the region of Santarém, Pará, in the state of Rondônia or in the Matopiba[72] region to find soybean farmers of southern origin who first did one or several "stops" in Mato Grosso before settling down there (Gaspar 2013; Adams 2015b). Others have simply returned to the South or decided to stay and started working in the fast-developing urban areas where they used to farm. The interviews have nonetheless shown that some farmers decided to sell their land but remained in the activity by either becoming the employee of another landowner or corporation (e.g. farm manager) or by joining the farm of a family member. *It is not the objective of this research to complete an exhaustive mapping of farmers' movements across several states*, so most information about these aspects will come from secondary sources or anecdotal evidence from the interviews.

Second, and obviously so, the interviews do not highlight the case of smaller farmers owning less than 2,000 ha.[73] The relative distribution of this sub-population varies from one municipality to the other **(See Table 2.1).** In Sorriso for instance, it is commonly reported that there are 600 farmers, of which 400 are affiliated with the local sindicato.[74] No more than 100 farmers would own 2,000 ha or more, a fact that seems to be confirmed by the latest agricultural census available

[72] New frontier of crop production in Brazil, starting in the 2000s, comprising the states of Maranhão, Tocantins, Piauí, and the western part of Bahia state.

[73] It is important to highlight that when speaking of property sizes of producers, the INCRA has an official classification based on the Fiscal Module (*Modúlo Fiscal* – MF) as a unit, which size vary depending on the state and municipality. In Sorriso and X for instance, the MF is 90 ha, whereas in other municipalities of this study it is 100 ha. Taking as a reference the 100 ha MF, the INCRA classification goes this way: small producers have an area inferior to 4 MFs (< 400 ha), medium producers are between 4 to 15 MFs (400 ha to 1,500 ha), large producers own over 15 MFs (> 1,500 ha). Thus, all the producers included in the study sample can be considered large-scale producers as per INCRA's classification. This classification, however, does not reflect well the reality of Mato Grosso's soybean producing regions where it is fairly common to have properties over 1,000 ha.

[74] Personal communication with the *sindicato* of Sorriso.

since there were 91 farmers over 2,500 ha in 2006 (**see Table 2.1**). In Sapezal, where the agricultural area is lower than that of Sorriso, but still comparable,[75] the local farmers' association (which I will further refer to with the Portuguese name *sindicato rural*, or *sindicato* for the short version) estimates that today there are only 60 producers since it is an area dominated by large corporations. An examination of the 2006 Agricultural Census reveals that there were 91 farmers in Sorriso and 89 farmers in Sapezal who owned more than 2,500 ha (IBGE 2017).

	BR-163								CHAPADA DOS PARECIS					
	Nova Mutum		**Lucas do Rio Verde**		**Sorriso**		**Sinop**		**Campo Novo do Parecis**		**Sapezal**		**Campos de Júlio**	
Size Category	*Owners*	***Area***	*Owners*	***Area***	*Owners*	***Area***	*Owners*	***Area***	*Owners*	***Area***	*Owners*	***Area***	*Owners*	***Area***
< 500 ha	560	**42,681**	194	**23,405**	642	**44,678**	944	**66,111**	112	**10,620**	7	**1,324**	9	**2,170**
500-1,000ha	61	**43,326**	56	**37,810**	121	**86,621**	56	**39,893**	26	**17,984**	10	**7,779**	20	**14,481**
1,000-2,500ha	59	**93,112**	47	**72,691**	131	**206,562**	44	**67,537**	72	**117,037**	24	**40,506**	36	**52,239**
>2,500 ha	55	**430,454**	17	**123,509**	91	**438,533**	23	**94,953**	69	**422,573**	48	**491,312**	31	**197,028**
Total	735	**609,573**	314	**257,415**	985	**776,394**	1067	**268,494**	279	**568,214**	89	**540,921**	96	**265,918**

Table 2.1. Distribution of producers in terms of number of farms and area (in hectares) by size categories of property for each municipality in 2006. Data from the Brazilian Agricultural Census (Censo Agropecuario 2006, tabela 837 - Número de estabelecimentos agropecuários e Área dos estabelecimentos por grupos de atividade econômica, condição produtor em relação às terras, tipo de prática agrícola e grupos de área total)

Table 2.2 confirms that a minority of large-scale farmers own the majority of these municipalities' areas. In 4 out of 7 municipalities included in this study, the class of landowners above 2,500 ha owns more than 70% of the agricultural area in 2006. In other municipalities (i.e. Lucas do Rio Verde, Sorriso, and Sinop), these farmers own less of the total area, but they represent less than 10% of the farmer population. Discrepancies between the number of farmers and the area owned can reach impressive gaps. In Nova Mutum, 7.1% of landowners own 70.6% of the land. In Sorriso, 9.1% own 56.5% of the total farmed area. In the Chapada dos Parecis, the land structure is more balanced as large-scale farmers dominate the total population of the municipality, with Sapezal being an extreme example of a municipality were the population is constituted mainly of

[75] According to the 2006 Agricultural Census, farmers in Sorriso cultivated over 776,394 ha while those of Sapezal over 540,921 ha.

large-scale farmers (i.e. farmers above 2,500 ha represent 53.9% of the farmer population and own 90.8% of the farmed area).

	BR-163								CHAPADA DOS PARECIS					
	Nova Mutum (%)		**Lucas do Rio Verde (%)**		**Sorriso (%)**		**Sinop (%)**		**Campo Novo do Parecis (%)**		**Sapezal (%)**		**Campos de Júlio (%)**	
Size Category	*Owners*	***Area***	*Owners*	***Area***	*Owners*	***Area***	*Owners*	***Area***	*Owners*	***Area***	*Owners*	***Area***	*Owners*	***Area***
< 500 ha	77.3	**7**	62.7	**9.1**	65.5	**5.7**	90.7	**24.6**	44.8	**1.9**	7.9	**0.2**	9.4	**0.8**
500-1,000ha	7.9	**7.1**	17.3	**14.7**	12.2	**11.2**	4.2	**14.9**	8.6	**3.2**	11.2	**1.4**	20.8	**5.4**
1,000-2,500ha	7.7	**15.2**	14.6	**28.2**	13.2	**26.6**	3.3	**25.1**	23.8	**20.6**	27	**7.5**	37.5	**19.6**
>2,500 ha	7.1	**70.6**	5.3	**48**	9.1	**56.5**	1.7	**35.4**	22.8	**74.4**	53.9	**90.8**	32.4	**74.1**
Total	100	**100**	100	**100**	100	**100**	100	**100**	100	**100**	100	**100**	100	**100**

Table 2.2. Proportion of producers and their area in each size category with respect to the entire planted area in the municipality in 2006. Data from the Brazilian Agricultural Census (Censo Agropecuario 2006, tabela 837 - Número de estabelecimentos agropecuários e Área dos estabelecimentos por grupos de atividade econômica, condição produtor em relação às terras, tipo de prática agrícola e grupos de área total)

The commonalities and heterogeneity in the land structure across the study area deserves a few remarks. The agricultural census of 2006 did not record more than 100 producers owning above 2,500 ha in any of the 7 municipalities (**Table 2.1**). However, the average area they owned in each municipality differed greatly, with an average area of 4,184 ha in Sinop as compared to an average area of 10,235.7 ha in Sapezal, the latter being dominated by large-scale family and corporate agricultural groups (**See Table 2.3**). On a more general note, the census confirms some interviewees' impressions that the land tenure was different between the two study regions. Farms are far larger in the Chapada dos Parecis area than in the BR-163 area. The average property area per producer is ranging from 251.6 ha (Sinop) to 829.4 ha (Nova Mutum) in the BR-163 selected municipalities while it is ranging from 2,036.6 ha (Campo Novo do Parecis) to 6,077.8 ha (Sapezal) in the Chapada dos Parecis region (**See Table 2.3**) These dissimilarities reflect a difference between the colonization history of both study regions, the BR-163 region being an older frontier that has also known a short period of cattle-ranching at the beginning and received a more important migration population than the Chapada dos Parecis region.

	BR-163				CHAPADA DOS PARECIS		
Size Category	**Nova Mutum**	**Lucas do Rio Verde**	**Sorriso**	**Sinop**	**Campo Novo do Parecis**	**Sapezal**	**Campos de Julio**
< 500 ha	76.2	120.6	69.6	70	94.8	189.1	241.1
500-1,000ha	710.3	675.2	715.9	712.4	691.7	777.9	724.1
1,000-2,500ha	1,578.2	1,546.6	1,576.8	1,534.9	1,625.5	1,687.8	1,451.1
>2,500 ha	7,826.4	7,256.2	4,819	4,128.4	6,124.2	10,235.7	6,355.7
Total	**829.4**	**819.8**	**788.2**	**251.6**	**2,036.6**	**6,077.8**	**2,770**

Table 2.3. Average property size in hectares by size category in each municipality in 2006. Data from the 2006 Brazilian Agricultural Census (Censo Agropecuario 2006, tabela 837 - Número de estabelecimentos agropecuários e Área dos estabelecimentos por grupos de atividade econômica, condição produtor em relação às terras, tipo de prática agrícola e grupos de área total)

The previous paragraphs demonstrated that, in these municipalities, a minority's decisions have an enormous geographical impact. It is now important to assess to what extent the sample of producers selected for this study represents this elite population. To compare the sample population of 2017 to that of the 2006 census, **Table 2.4** only compares producers in the sample that own over 2,500 ha (n=90, with an area of 1,049,016 ha) to match with the 2,500 ha farm size cutoff of the agricultural census. With an average of 15 producers interviewed in each municipality, sampled producers represent from 17.5% (Sinop) to 70.6% (Lucas do Rio Verde) of the large-scale farmer population in each municipality. **Table 2.4** further demonstrates that sampled producers represent an even larger geographical footprint than the ones included in the census. The controlled area sometimes exceeds the maximum area owned by census producers above 2,500 ha. This can be explained by the fact that producers included in the study not only declared the area they control (own and rent) in the municipality of the interview, but also in other neighboring municipalities and states (See explanatory note below **Table 3.4**).

	BR-163								CHAPADA DOS PARECIS					
	Nova Mutum		**Lucas do Rio Verde**		**Sorriso**		**Sinop**		**Campo Novo do Parecis**		**Sapezal**		**Campos de Júlio**	
Size Category	*Owners*	***Area***	*Owners*	***Area***	*Owners*	***Area***	*Owners*	***Area***	*Owners*	***Area***	*Owners*	***Area***	*Owners*	***Area***
Number of ITWs > 2,500 ha	15	**124,600**	12	**150,712**	16	**172,290**	11	**190,764**	13	**90,345**	12	**205,952**	16	**172,290**
(1) Share of census farmers >2,500 ha	27.3%	**28.9%**	70.6%	**122%**	17.5%	**39.3%**	47.8%	**201%**	18.8%	**21.4%**	25%	**41.9%**	51.6%	**97.4%**
(2) Share in total census farmers	2%	**20.4%**	3.8%	**58.5%**	16.2%	**22.2%**	1%	**71%**	4.6%	**16%**	13.5%	**38.1%**	16.7%	**64.8%**

Table 2.4. Sample representativeness by partially comparing interviewees from the study (n=90 producers > 2,500ha) to (1) the class of producers above 2,500 ha and (2) the total municipal population of farmers of the 2006 agricultural census. Note: Restricting the comparison to sample producers above 2,500ha only takes out 14 individuals and 27,136 ha, which is only 2.5% of the sample area. Note 2: Producers in the study sample declared the area they controlled in and outside the municipality where the interview took place. Hence, the percentages can go above a 100% because they may own large extent of lands in other municipalities. Data from the Brazilian Agricultural Census (Censo Agropecuario 2006, tabela 837 - Número de estabelecimentos agropecuários e Área dos estabelecimentos por grupos de atividade econômica, condição produtor em relação às terras, tipo de prática agrícola e grupos de área total)

Focusing on the large-scale population of soybean producers presents several advantages and offers novel insights into the colonization history of Mato Grosso. It is perhaps the only way to illustrate the diversity of paths that led some individuals to access large land estates. Farmers' life trajectories, migration paths, and terms of land access are far more convoluted than previously assumed, notwithstanding the fact that some of those farmers were not even farmers before arriving into the region (although they often had parents who farmed in the South). The literature on Amazon colonization has inadvertently popularized an image of frontier colonizers as fitting two main profiles, following the *turnover hypothesis* cited above (Campari 2005). On the one hand, there is the poor smallholder who would migrate to a small land lot, fail at tropical agriculture, and sell his land plot after clearing part of it to move further down into the Amazon. On the other hand, there are the survivors of this particular frontier (the "successful" farmer) who would buy up the others' land and who would be joined in the same endeavor by the more capitalized farmer arriving in the frontier at a later stage, taking advantage of partly cleared land plots.

The following review of the biographic data contained in the interviews demonstrate that this image is quite a rough approximation. Although unable to observe those who 'fail' or are 'pushed away' following various pressures in a changing and modernizing frontier, the data illustrates a variety of previously unexplored patterns. Some landowners bought and sold land in an area just to make a profit in the early years of colonization while others are still doing this today. Some sold land to consolidate more land plots together in another location (hence they do not "leave" the frontier to get to another one). Some of the first farmers (pioneers) arrived already capitalized in the early days of the colonization, so the colonization is not only comprised of poor humble farmers.

1.2. METHODOLOGY

I chose here to illustrate the study results by showing a reconstitution of the life stories of a few farmers based on the interviews. The semi-structured interviews applied during this study contained a section that was biographic in nature to understand the key life events and formative experiences of the interviewee regarding geographical movements (location and year), education, family events (marriages and children), land purchases and rentals, property clearing history, and crop cultivation information. Apart from a few questions to start off the discussion (such as asking the location and year born, or what the farmers did prior to migrating), this part of the semi-structured questionnaires was conceived as a freely-flowing discussion leaving as much flexibility as possible to the interviewee for reporting life events. The information was recorded in writing on a paper sheet with a printed table on it with a hundred horizontal lines corresponding to possible ages of the interviewee and columns corresponding to the categories of key life events mentioned above.

Following the interview, the information was transcribed in a word document summarizing the life story of the interviewee in chronological order (which most of the time respected the same order with which the interviewee shared information about his/her life events). I reformulated those events into a narrative getting as close as possible to the words and tone of the interviewee, strictly respecting the key events and information reported by the interviewee. Since the interviews were not recorded for reasons explained earlier (See Introduction), I have omitted digressions which were not representing new information, or which were simply not related to the main objective of the study. This organization of the data allows for a better understanding of life trajectories as if the interviewees had "rolled out" their lives chronologically and helps to capture the key choices and junctures of the colonization history of Mato Grosso.

2. THE LIFE TRAJECTORIES OF SOYBEAN PRODUCERS

I chose to show the life trajectories of five farmers illustrating the diversity of colonization profiles among actual large-scale landowners. Although today these farmers often appear to share generally similar characteristics, their early-life stories demonstrate some differences in their background, migration paths, and stories of land access.

2.1. EXAMPLES OF LIFE TRAJECTORIES

Example 1: A capitalized farmer family on the BR-163 frontier (ITW n°004)

	Birthdate & Place of origin	Education	Time of arrival	Land size in the South	Size & Date of 1st property	Controlled area today	Soybean area (main property)	Corn area (main property)	Cotton area
Farmer n°1	1980, Paraná	Law college degree	2004	N/A	13,000 ha (1978)	8,500 ha	4,400ha	4,200ha	0ha

Table 2.5. Descriptive characteristics of farmer n°1. Note: the difference between area controlled and soybean area is because farmers were asked how much land they control on the one hand, and how much soybean they plant on their *main property* on the other.

This property of this farmer is located in a remote part of the municipality which took a day of travel to access in the 1970s from the town and is now only a 45-minutes drive on a paved road perpendicular to the BR-163. The road is punctuated from time to time by giant crop silos owned by local farmer cooperatives or commodity export multinationals. Turning down the farm road, one still has to drive for another ten minutes under a continuous corridor of bamboo trees providing much-needed shade before reaching the headquarters of the farm. This farm is a typical estate in the region, producing soybean and corn.

This young farmer (37 years old) was born in Paraná and took up the farm of his grandfather since his death in 2011. Originally from Rio Grande do Sul (RS), his grandfather had followed a well-known migration path during his life. Very early, he moved from RS to Santa Catarina where he managed to have a timber exploitation and a flourmill. After a while, he decided to abandon the timber activity and, since the government was controlling the flour prices, he moved to Paraná with hopes to diversify the activities of the family economic group. Looking to expand further, he started traveling Brazil in search for new lands. He went to Mato Grosso do Sul, near Campo Grande, but "the land there were expensive, they had already gone up in value" (ITW n°004). He finally decided to buy land in Mato Grosso in 1978 and started rice cultivation and cattle-ranching

there, but after one of his sons almost died, he sold the land. He came back later to "buy land from the INCRA." In fact, the grandfather started occupying 13,000 ha of land without any authorization or titles (under *posse,* presumably), but he later regularized them with the INCRA by paying a fee. In the words of the interviewee: "when the INCRA made the land available, he [the grandfather] bought them (…) he had to bring INCRA's superintendent of Cuiabá tocertify that the land was cleared and recognize an official title." Interestingly, his uncle was spending the money necessary to clear his land and that of a neighbor, the latter was in charge of doing the manual work while the grandfather was coming back and forth from the South by plane. Obtaining a legal title in 1982 helped them face better the "ill-intentioned neighbors" coveting their land.

The interviewee came to Mato Grosso in 2004 (at around 24 years old) to start managing the property after completing a law degree. Since the time of his grandfather's first purchase, the family did not buy much land and even had to sell a piece in 1997 following an internal economic crisis in the family group. The entire enterprise of colonizing new land in Mato Grosso was indeed linked and funded by the revenues generated by flourmill activities in the South. The interviewee administers the farm today with a cousin and a "trusted employee" of his grandfather. Still organized as a family group with diverse activities in the South and in Mato Grosso, the interviewee hopes one day to separate the farm from the rest of the group.

Example 2: Arrival alone of an employee of farm cooperative in the BR-163 region (ITW n°008)

	Birthdate & Place of origin	Education	Time of arrival	Land size in the South	Size & Date of 1st property	Controlled area today	Soybean area	Corn area	Cotton area
Farmer n°2	1970, Paraná	No higher education	1987	0 ha	400 ha (1996)	8,000 ha	5,500ha	3,000ha	0ha

Table 2.6. Descriptive characteristics of farmer n°2. Note: the difference between area controlled and soybean area is because farmers were asked how much land they control on the one hand, and how much soybean they plant on their *main property* on the other.

This farmer, born in 1970 in Paraná, arrived in the area during the second wave of migration in the region toward the end of the 1980s (in 1987). With no higher education and bare minimum schooling, he left alone for Lucas do Rio Verde at 17 and started working as a storage unit manager for a crop cooperative. In 1993, he started working for an input reseller (called *revenda* in Portuguese) and only 3 years later he created his own *revenda*, starting by buying and selling small quantities of inputs. As a business owner, he faced the major challenge of providing a collateral to get credit from the bank and from his input providers: "so that my activity grows, I had to buy more land. I was buying small scattered pieces, from various producers, 150 kilometers from here." He thus started to acquire land in the municipality of Tapurah (the neighboring municipality of Lucas) to serve as collateral when taking loans from the multinational BASF. The land was still cheap in the 1990s as the municipality was still a frontier and far from the main transport infrastructures.

Slowly, he accumulated land piece by piece at a 150km road-distance from Lucas and by a stroke of luck one day, a road was built to the neighboring municipality of Ipiranga do Norte, reducing that distance to 50km. Consequently, the lands went up in value and he decided to start farming on them. Today he has sold his *revenda* to dedicate himself to planting on an area of 6,500 hectares. Not all members of the family had a similar trajectory: "in the family we are 5 brothers. The one

who was an employee here passed away recently. In the region, I have another brother in Sinop and one in a *chácara*[76] (I am the owner). He sells tomatoes and lettuce by the road."

Example 3: "The PRODECER was my second mother" - Private-Public colonization with the PRODECER program (ITW n°017)

	Birthdate & Place of origin	**Education**	**Time of arrival**	**Land size in the South**	**Size & Date of 1st property**	**Controlled area today**	**Soybean area**	**Corn area**	**Cotton area**
Farmer n°3	1961, Santa Catarina	No higher education	1985	~24 ha (parents)	400ha (1986)	2,870 ha	2,100 ha	2,100 ha	0ha

Table 2.7. Descriptive characteristics of farmer n°3. Note: the difference between area controlled and soybean area is because farmers were asked how much land they control on the one hand, and how much soybean they plant on their *main property* on the other.

Born in Santa Catarina (SC) in 1961, this farmer's parents were small producers who had to emigrate from RS because of a lack of land there. At 24 years old, the interviewee decided to leave for Paraguay and rented land there for 2 years. During this time, he married someone in SC and decided to return because he could not get along with people in Paraguay. As a solution, his father and uncle rented land for him in Nova Mutum, Mato Grosso in 1985. With his spouse, he moved to this area and started planting.

[76] Small countryside house associated with a few areas where to plant vegetables

Soon after, however, an opportunity came up:

> *"At the time there was a Japanese program, the PRODECER, and in 1986 they would give 400 hectares land lot, fully financed with 2 tractors and a harvesting machine. One day I heard of this project and I went to Lucas. I heard they were funding the land clearing. At the time I was crazy at the idea of buying only 100 hectares! I went to their office and they had 200 applicants for only 40 lots. They told me there was a similar project in Tapurah but I had no desire to go there. So I just registered and went away. At the time, there were many people who did not want to get this land by fear of depending from the Japanese (…) 6 months later, by accident, I came back to Lucas and thought I should visit their office. They informed me that only 30 applicants had remained, that everybody had given up. They offered me to participate in the program, I only had to register at the bank which was located in Diamantino. I had 8 days to do so. Later they would bring me to the lot which was fully covered in forests."*

Benefitting from the PRODECER which was a "second mother" for him, he then consolidated his property by buying around it, always through exchange of crops. In 2004 he bought 2,800 ha in Nova Ubiratã (a municipality stretching east from Lucas up to the Xingu Indigenous Park) with a business partner but sold it in 2010 as he separated from him. He managed to buy an additional 1,200 ha of land in Lucas and now owns a property equivalent to 2,870 ha.

Example 4: Poor farmer's family, passing through several states before arriving in the Chapada dos Parecis (ITW n°049)

	Birthdate & Place of origin	**Education**	**Time of arrival**	**Land size in the South**	**Size & Date of 1st property**	**Controlled area today**	**Soybean area**	**Corn area**	**Cotton area**
Farmer n°4 (Mother)	1953, Santa Catarina	No higher education	1983	~3 ha	2,400 ha (1983)	3,290 ha	1,300 ha	1,300 ha	0ha

Table 2.8. Descriptive characteristics of farmer n°4. Note: the difference between area controlled and soybean area is because farmers were asked how much land they control on the one hand, and how much soybean they plant on their *main property* on the other.

This (female) farmer came to Mato Grosso with her (now deceased) husband after several movements across the South to Mato Grosso migration path. Originally from Chapéco, SC, where she was born in 1953 in a family of Italian origin (nationality of the great-grandparents), her

parents had a chicken farms and were the suppliers of a large company: “at the time, the guys were financing you and you were their employee almost becoming their slaves.” In 1973 she married her husband and together they earned 3.2 ha. They decided to try their luck emigrating to Mato Grosso do Sul to get larger land to cultivate, despite her family’s reluctance. She told me, with her son present in the room, that “my mother , my father, cried a lot. They did not want us to sell the land. They told us we would barely survive. As a result, they did not let us sell our land and this caused us a lot of suffering because it left us with no resources to purchase land.”

The couple moved to Sao Gabriel do Oeste, MS, in 1975 to rent out 700ha land. Since they had no resources, they offered the owner to clear his land in exchange of planting rice there. “We were living below a tent, we cleared 700 hectares with no resources. We just had a CBT tractor and we worked day and night.” Unsatisfied with such a tough life, they started looking for land in MT in 1980. Once they made enough money with rice cultivation in MS, they moved up to Campo Novo do Parecis and bought 2,400 ha of land regularized by the INCRA. They cleared the land gradually, piece by piece, and even received the help of a wealthier neighbor who planted in their land for free over the course of five years in exchange for this service. They were not able to start planting soybean there until 1988.

The interview of this farmer and her son offered a glimpse at the difficult life conditions of the first settlers of the municipality of Campo Novo do Parecis. She said that “we suffered a lot, there was no road, no hospital, and it was taking us 8 days to get to Tangará [a neighboring municipality which today is 3 hours by car] (…) When we were going to Tangará da Serra, we had to go through

Itamaraty[77] and I was scared to go there because they were a lot of gunmen there. We stopped in the middle of the road and my husband wanted me to sleep in the truck with our daughter while he would go sleep on top of it with our two sons. In the morning, a truck came with 3 persons starving to death, they did not have water so we shared some with them along with some honey we had. Many people who were going to Juína were dying on the way at the time."

These four examples are hardly generalizable but they illustrate how diverse the life trajectories of the colonizers of the BR-163 and Chapada dos Parecis regions are. Beyond a common cultural and economic origin (smallholder farmers in the South of Brazil) and a shared journey to Mato Grosso, general narratives about this period of history tend to obscure the specificity and complexity with which some of the settlers were able to remain in activity in the area, if succeeding at all. This chapter sheds light on the fact that large-scale landowners are the complex result of various types of land access, family and economic configurations, strokes of luck, and personal persistence. In the next sections, I attempt to synthesize what I learned from the stories of 104 interviewed farmers and examine the implications for the colonization history of Mato Grosso.

Example 5: Pioneer smallholder becoming one of the largest producers in his municipality (ITW n°032)

	Birthdate & Place of origin	Education	Time of arrival	Land size in the South	Size & Date of 1st property	Controlled area today	Soybean area	Corn area	Cotton area
Farmer n°5	1953, Rio Grande do Sul	No higher education	1979	120 ha	726 ha	24,000 ha	10,300 ha	10,000 ha	0 ha

Table 2.9. Descriptive characteristics of farmer n°4. Note: the difference between area controlled and soybean area is because farmers were asked how much land they control on the one hand, and how much soybean they plant on their *main property* on the other.

[77] Name of a locality between Tangará da Serra and Campo Novo do Parecis

This old pioneer producer is one of the first farmer to arrive in Sorriso, and also one of the largest (24,000+ ha) today. This landowner come from a family who was originally doing subsistence farming in Rio Grande do Sul. There he had 6 other brothers (3 brothers and 3 sisters). When he was 3 years old, his parents moved to Renascença,[78] Paraná, for expanding land and opening sawmills (1953), a migration that many were undertaking in the South at the time. The family's objective was to exploit the araucaria and pine trees of Western Paraná. His father purchased with his sons lots of 70 ha for each sons, and they ended up planting only 120 ha.

In 1976, he heard about the colonizadora Feliz selling land in Sorriso, as the main colonizer was the friend of his father. As he had just got married, he bought a 726 ha lot from the colonizadora in 1976. He bought the land because of the topography (i.e. flatness) and climate. He however kept working on his father property and only made it up there in 1979, three years later, to start clearing land with the help of two cousins. Together during 3 years, they cleared the land using *correntão* and burned the wood during the dry season. Each of them opened up 100 hectares but they then separated. It was difficult for them to access credit from the national bank (i.e. Banco do Brasil) at the time, and they did not end up using the money made available by official programs like POLOCENTRO (for machinery) and PROTERRA (for land purchase). In 1982 they started planting soybean. As the cost of gas increased, they started experimenting with no till techniques early on, around 1983. However, it did not yield good results and returned to it only after 1986. He told me "I am going to tell you one thing, if it was not for no till, there would be no agriculture here." It is only with the installation of the local Banco do Brasil in Sorriso that financial conditions improved for them (before then they had to travel all the way down to Rosário Oeste).

[78] This name, "rebirth" in Portuguese, tells a lot about the significance of migrating to Paraná for small farmers from Rio Grande do Sul looking for new economic opportunities

He kept adding up land over the years, partly purchasing from the colonizadora and partly from other people (second-hand, *posse*). He however bitterly regrets to have purchased from the colonizadora Feliz because it led to many land titles issues and insecurity. He said that the land titles sold by the founder Claudio Francio were in fact public lands (*terras devolutas*) that did not have a proper title. In contrast, it prove much easier to obtain land titles for land under *posse.* In 1998, he sold all his original lands in Sorriso to his cousins and bought a large 7,000 ha property in Sorriso, which he consolidated today with other properties into a 14,000 ha property. Diversifying investments, he created an inputs reseller store (*revendas*) in 2007. In 2008, he expanded his activities by buying a 9,000 ha property in Nova Ubiratã (East of Sorriso) and in 2011 also bought a 3,000ha one in Santa Carmem (Northeast of Sorriso). In 2013, he further diversified and entered as a partner in a *revenda* of agricultural machines.

Today one of his sons is in charge of managing the farm, while he administers the farm (financial part) with another of his son and his brother. He also has a daughter who is in charge of the financial management of the *revenda*. He foresees an upcoming division of the property since he administers the farm with his brother.

2.2. LIFE TRAJECTORY: A MODEL

From these examples and the wealth of information provided by 104 interviews, it is possible to attempt the formulation of a model of life trajectory that represents an "average" or "classic example". The first phase corresponds with the decision to migrate (**See Figure n°2.1.1** "MIGRATION & PURCHASE"). Most farmers chose to emigrate to Mato Grosso following a

common assessment: there was not enough land to support agricultural family activities in their state of origin. Born in one of the three southern states of Brazil (Rio Grande do Sul, Santa Catarina, Paraná), they teamed up with family members (fathers, brothers, uncles, cousins), friends, or business partners and ventured out to buy land in Mato Grosso, often brought there by a *colonizadora*. This allowed them to trade their original land of 20 or so hectares for around 500 ha. Others visited a given place but decided to buy larger land plots (around 1,500 ha) under the insecure status of *posse* (they would either invade the land themselves or buy it from third parties who had roughly delineated the land).

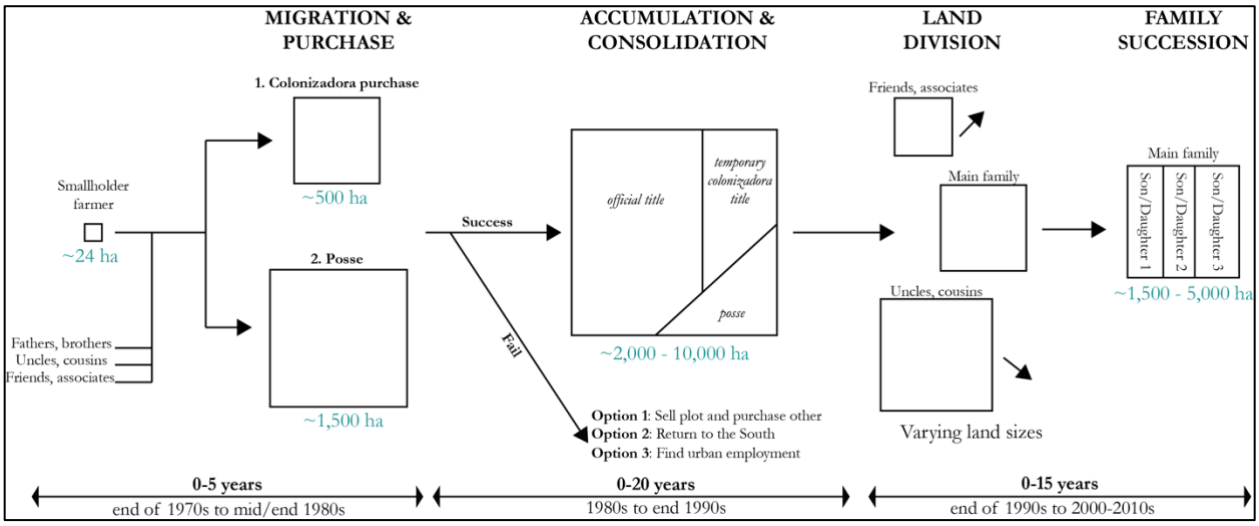


Figure 2.1. A model of life trajectory of a farmer family from the South to Mato Grosso.

Once settled, farmers engaged in the gradual clearing of native vegetation (i.e. one of the many gradients of Cerrado vegetation or forests) (**See Figure n°2.1** "ACCUMULATION & CONSOLIDATION"). They usually cleared 100 ha to 200 ha each year, and then planted rice to prepare soils for soybean cultivation. During the period extending from early colonization (end of the 1970s) to the mid-1990s, a majority of colonizers failed at producing crops efficiently and had to either return to the South or sell their land to start over in another municipality where land was cheaper. Many of these early "failures" can be seen in the histories of farmers in more recent

agricultural frontiers of the Legal Amazon, like in Maranhão (Gaspar 2013). If successful, farmers would take advantage of others' failures and buy their land to accumulate and consolidate larger land estates. This way, they often owned properties with different land tenure statuses ranging from official land titles from public bodies (e.g. INCRA, INTERMAT[79]) to *colonizadora*-titles or mere *posse*. As farmers progressed and turned properties into profitable soybean farms, many of these ventures separated to reorganize themselves around the nuclear family (**See Figure n°2.1** "LAND DIVISION"). The once small group of brothers and cousins became a large group as children began participating in the activity. The family and business partners of the original migration parted ways to continue the activity on their own, reducing the total land area operated by each individual. Thus, many families divided the properties to be able to manage areas within the family unit of parents and children.

Finally, toward the end of the 1990s and the beginning of the 2000s, parents who were the initial pioneers had become too old to manage their farms (**See Figure n°2.1** "FAMILY SUCCESSION") and subsequently decided to transfer their land inheritance to their children. This process, called "family succession," resulted in the division of large properties, and it is not rare to see families who collectively owned around 8,000 ha (at the time of family ventures) to return to 1,500 ha. Since some of the farmers' children did not want to take up their parents' activities, many families opted to transfer all land to a family corporation (of which shares would be owned by all). This permitted the family members who wanted to take up the activity to rent their part of inherited land property to their brothers and sisters.

[79] The Mato Grosso Land Institute (Instituto de Terras do Mato Grosso – INTERMAT) replaced the Geography and Geology Department of Mato Grosso's Agriculture Secretariat in 1976 by Decree n°775 of November 23.

This simplified view of farmers' trajectories in the Alto Teles Pires and Chapada dos Parecis frontiers falls short of reflecting the real diversity of trajectories. However, this model helps identify the key transformations farmer families experienced from the initial settlement stage to that of a consolidated frontier. As I will outline in Chapter 3, most deforestation occurred during the "Accumulation & Consolidation" phase, but other deforestation was caused by the changes provoked by land divisions and family succession which prompted some individuals to look for additional land to reconstitute properties of larger size. In the next sections, I describe the diversity of family characteristics (not all families began as smallholders) and the convoluted paths that farmers' lives have taken during the course of Mato Grosso's colonization.

3. A COMMON ORIGIN, THE SOUTHERN STATES OF BRAZIL

3.1. BIRTHPLACE AND SOCIO-ECONOMIC CHARACTERISTICS OF FARMER FAMILIES

In spite of the heterogeneity of their trajectories, the soybean producers of these two study regions undoubtedly share a common geographical origin in the South of Brazil. Of the 96 different families surveyed in this study (104 individuals), 36 individuals were born in the state of Rio Grande do Sul (RS), in the very south of the country (**see Table n°2.10**). The second and third largest groups of origin are the states of Santa Catarina (SC) with 26 individuals and Paraná (PR) with 23 individuals, both of which are located right above Rio Grande do Sul. Nevertheless, many of those individuals had parents who were born in Rio Grande do Sul and were only born in Santa Catarina and Paraná a few years after their parents had emigrated from there. The remaining interviewees (less than 20%) come from other states like Mato Grosso do Sul (MS), Goiás (GO), Sao Paulo (SP), or Minas Gerais (MG). Within this group, a few were born from Mato Grosso (MT), but they are the sons of producers from the South, so they can be considered Mato Grosso's

second-generation farmers. One exception however is a farm manager in one of these municipalities, who is the son of a poor family of farmers who had been in Mato Grosso for generations. The striking point here is that none of these landowners or their families come from northeastern states like Maranhão, which had constituted the human base of colonization programs in Pará during the 1970s and 1980s. This makes this farmer population of Mato Grosso ethnically and culturally homogeneous (Le Tourneau and Droulers 2000).

Almost all these families have European roots and the interviewees seemed to systematically and spontaneously mention this aspect at the beginning of the interview. When talking about their origin and location of birth, they pointed out that their grandparents or great grandparents were Italian, German or Polish. This European descent is due to the intense wave of immigration experienced by Brazil at the end of the 19th century and beginning of the 20th century. Between 1888 and 1940, 4 million Europeans emigrated to Brazil, with 1.3 million between 1888 and 1898 (Droulers 2001: 182). Many German, Portuguese, and most of all Italian migrants came to work either in the coffee plantations of the state of Sao Paulo or to colonize the southern state of Rio Grande do Sul, causing a cultural shock between the traditional *fazendeiro* (i.e. traditional name of farmers in Brazil) and their agricultural tradition. Around the turn of the century, many Japanese emigrated to work in the coffee plantations.

Municipality	Farmers' count	State of origin			
Chapada dos Parecis		**RS**	**SC**	**PR**	**Other**
Campo Novo do Parecis	14	5	3	2	1 (SP); 1 (MS); 2 (MT)
Sapezal	15	2	1	8	4 (MT)
Campos de Júlio	13	5	1	4	1 (GO); 2 (MT)
BR-163					
Nova Mutum	18	5	7	3	1 (SP); 1 (GO); 1 (Switzerland)
Lucas do Rio Verde	13	5	4	2	1 (GO); 1 (MT)
Sorriso	16	8	3	2	1 (SP); 2 (MT)
Sinop	15	6	7	2	-
TOTAL	**104**	**36**	**26**	**23**	**18**

Table 2.10. Birthplace of the surveyed soybean producers distributed by the three states of the southern cone of Brazil (total observations n=104).

The origin and birth year of these farmers reflect the location of families of smallholder farmers along a well-known colonization path in Brazil. In the 1950s and 1960s, the expansion of mechanized agriculture in the Southern states (Rio Grande do Sul, Santa Catarina, Paraná), associated to growing soybean cultivation (a production system almost 100% mechanized) (Wilkinson and Sorj 1992), changed the economic viability of farming in the South and made it almost impossible for these farmers to survive on small land plots. Mechanization demanded larger areas and also represented larger gains. This pressure was magnified by the fact that families of farmers often had around 10 to 12 sons and had to divide land between them, leaving only two choices: buy more land to support the livelihoods of the whole family or let their sons go work for a wealthier farmer or in urban areas. Faced with this prospect, many smallholder families -or their children- decided to emigrate from Rio Grande do Sul to either Santa Catarina or Paraná, as both states were still frontiers and offered larger areas to cultivate. Some left for Santa Catarina and then moved to Paraná just a few years later (if they did not succeed there or had socio-economic reasons to move again) while others went straight from Rio Grande do Sul to Paraná to find agricultural land twice the size of what they owned in Rio Grande do Sul. A few took the

opportunity of this move to change their activity and started working in timber extraction in Northwest Paraná.

While mainly focusing on agriculture, some families had a diversified source of income represented by side-activities such as truck transport or local supermarkets. Wealthier families sometimes owned wholesale stores (*atacadão*), flourmills, and sawmills. These activities were structured around the members of a single family and took the form of a corporate group. Some of the families who emigrated to Mato Grosso still organize based on this same group while keeping their original activities in the South. In a few cases, the rent generated by these activities helped finance the migration and settling on new land, with some family members remaining in the South while others ventured to MS or MT in search for new agricultural opportunities.

3.2. The choice to emigrate to Mato Grosso: multiplying land area, a family group endeavor

The overwhelming majority of farmers surveyed in the study came from families who originally owned a small plot of land ranging from 24 to 48 ha.[80] Unable to provide their sons with a future in farming in the South, the families took the decision to emigrate to new frontiers in search of larger areas to cultivate. Except for capitalized farmers, this entailed selling the land plot in the state of origin to buy a new one in the state of destination, thus effectively "trading" one land for another. Depending on their economic situation and, most importantly, timing of emigration, such humble families from Rio Grande do Sul could hope to get between 70and 120 ha in Santa Catarina

[80] Many interviewees referred to their parents owning a "sitio" which had the standard size of 24 hectares in the South

or Paraná. It was indeed easier to find larger areas in these two states in the 1950s or, later in the 1960s, in remote parts of those states in towns that constituted the last frontiers to be explored.

While it is hard to assess the number of families for whom a movement from Rio Grande do Sul to these two states was successful, it was not necessarily the 'end game' for the families surveyed in this study. After some time residing in those states, many families decided to emigrate again, especially given the fact that most affordable land in Paraná had been occupied by the end of the 1970s, which forced them to look elsewhere. As Wilkinson & Sorj explain: "by 1980 the frontier for soybeans in the southern States had been exhausted and cultivation oscillated around 3,500,000 ha throughout the decade" (Wilkinson and Sorj 1992: 25). Those who went to Santa Catarina made one more jump to Paraná or went straight to Mato Grosso do Sul or Mato Grosso, joined by other migrants from Paraná, always attracted by opportunities to multiply the land area they could cultivate. Once again, the choice of location depended on the economic conditions of the family and the timing of migration. Generally speaking, one could get between 100-200 ha of land in Mato Grosso do Sul, but approaching the late 1970s and 1980s, most migrants preferred to go to Mato Grosso directly because they could get as much as 250-1,500 ha there. During my conversations with farmers, it was not rare to hear stories of migrants from the South who traded a good, like a truck, for 2,500 ha of land (although probably with unsecure land titles and a less accessible part of a municipality).

This study aims to re-emphasize the fact that the migration to Mato Grosso was an extended--family endeavor and that very few individuals undertook the journey alone with only the nuclear family. The decision to emigrate was often taken by the patriarch of a family in conjunction with

other members of the family such as brothers, a father or an uncle, cousins, or even already-married sons. In the 1970s and 1980s, a subset of them would travel together to various locations in Mato Grosso, or to various other states (Mato Grosso do Sul, Rondônia, Tocantins, Goiás, Bahia, Roraima, etc.) in search for land. Interviewees described how their father scouted out for land in various places before deciding to settle in Mato Grosso:

> *"In 1978, my father traveled around a lot by car and by plane in order to decide where to settle. He often traveled with the idea of settling in Mato Grosso but, on the way, he would stop by northern Paraná, by Mato Grosso do Sul. He stopped by to get to know and talk to people there. He finally decided to purchase in Sorriso. His criteria to decide was the price (the most important), the presence of people he already knew there, the climate, and the topography" [ITW n°031]*

> *"Already in 1980 my father had bought a 480 hectares farm in Goiás, in the municipality of Jatai, using the money of the sale of the house and the beach apartment we had in the south. At that time, everybody was looking for land. We went to various places before deciding (…) we sold the farm in Goiás because we concluded that there were any more opportunities to grow there (…) So we got out to look up for land everywhere: Brasília, Bahia, Tocantins. And, finally, we arrived in Campo Novo. Our objective was to buy as much land as possible, raw land, and the cheapest possible" [ITW n°039]*

Farmers were not reluctant to travel long distances to analyze what the best opportunity would be. A single colonizadora could have offices in several southern municipalities and would propose to fly in potential colonizers over the areas to be sold, once they had paid their bus ticket to get to Cuiabá. Other colonizers would take advantage of their truck driving activities to explore different areas. One farmer mentioned that his father traveled with a group using a VW beetle up to the dirt roads of Porto Velho, Rondônia, in order to explore all opportunities. Other colonizers did not go such a long way and simply "jumped" on the opportunity offered to them by the colonizadora, or when they heard from a family or acquaintance (both of which could be active employees of colonizadoras) that some land plot was available:

> *"In 1976, I bought 726 hectares from the Colonizadora Feliz. There was a friend of my father who was re-selling agricultural machines in the neighboring town. He was a friend of Claudio Franzio.*[81] *An opportunity to buy land appeared. The climate was favorable and the flat land easy to clear" [ITW n°032]*

A fair number of farmers bought the land they visited when a colonizadora paid for their trip to visit Mato Grosso. Others even paid for the land but did not move to its location until after a few years, when they heard that the experiences of others were working.

> *"At the same time [i.e. late 1970s], my two elder brothers went to Mato Grosso as the family did not have enough land for the growing family. In truth, they first went to Tocantins to look up for land but found the soil very sandy. They were using the services of a colonizadora. There were various colonizadoras which were bringing southerners to the Center-West to look at land. In the end, they were brought to Nova Mutum by a colonizadora called "Berre Fértil" if I remember well. They bought a 400 hectares lot" [ITW n°007]*

The evidence set forth in this section shed lights on the *process* followed by colonizers when choosing land as well as the *criteria*. Farmers would look at various factors when choosing where to buy land: price, climate and rainfall patterns, soil, and -importantly- the presence of relatives. To be sure, the price would often be the most important. Nevertheless, since farmers were making this transition in groups composed of family members, friends and business partners, it is not surprising that they frequently mentioned the presence of relatives as an important criterion for deciding the final location of the purchase. As chapter 2 will demonstrate, the process of occupation and land clearing relied a lot on the help and solidarity of groups of like-minded colonizers from the South. The choice of land and location of immigration is only one aspect of the diversity of strategies with which people accessed land in the frontier and which I will discuss in the next part as it represents a key unexplored aspect of Mato Grosso's colonization.

[81] Claudio Franzio is the founder of the *Colonizadora Feliz* in Sorriso

3.3. THE TIMING OF EMIGRATION AWAY FROM THE SOUTH

Colonizers from the South have come to Mato Grosso in three main successive "waves." The first period corresponds to the late 1970s and early 1980s (1974-1982 on **Figure 2.2**) and features the pioneers of those region. These colonizers were the ones to buy land from colonizadoras but also occupying *terras devolutas* under posse. Of this first period, barely a quarter or a fifth of original migrants remain today, as many have encountered unsurmountable difficulties according to some interviewees (e.g. ITW n°062). A second wave of colonization occurred in the late 1980s and peaked around 1985-1987 (1982-1990 on **Figure 2.2**) and saw relatively more capitalized farmers joining in the region as compared to the initial settlers. However, making such a unilateral and direct link between capital and time of arrival would be illusory as some of the interviewees within that period did not appear especially different from the initial settlers. Finally, the 1990s saw the arrival of a third wave (1991-1997 on **Figure 2.2**) of professional and capitalized farmers from the South looking to expand the scale of their operations which can be seen on the figure with farmers arriving mostly between 1994 and 1997. Four individuals arrived after 2000, but they all had family involved in farming in the area, except one colonizer who came from the South to reproduce what many southerners did in the 1980s. Producers shared their perception that the migration waves of the 1970s and 1980s were mostly due to poor southern farmers while those of the 1990s and 2000s were due to capitalized farmers already successful in the South [ITW n° 062, 066].

The median age of the 104 interviewees of this sample is 52 years old. Ruling out individuals born in 1980 as they all are second- or third-generation farmers in the area, the average year of arrival in Mato Grosso is 1984 (n=79). Of this subset of the sample, 21 individuals arrived before

1980 demonstrating that the sample contains a reasonable amount of "pioneers," i.e. farmers who arrived in the first wave of colonization when the study regions were lacking infrastructures and had barely experienced agricultural production. This small number is fairly consistent with reports by farmers that barely 20% of original settlers have made it through the turbulent evolution of agriculture in the region. 41 individuals arrived with the second wave of migration between 1980 and 1989. Although this second wave of farmers is said to have arrived in the mid 1980s, **Figure 2.2** shows that the situation is more complex since migrants have steadily arrived between 1981 and 1989. Finally, 17 individuals arrived from 1990 onwards describing a category of farmers who migrated "late" in the region. As discussed in section 3.4.2, these are generally more capitalized farmers who had successful operations in the south and wanted to expand them further. I have nonetheless met with a few young farmers who were smallholders in the South in the 2000s and migrated in the hopes of cultivating larger areas just like the colonizers of 1980s. These farmers may have heard of an opportunity to join an already established frontier and bought a small plot there or a bigger area in remote areas of a municipality, farther from the main roads.

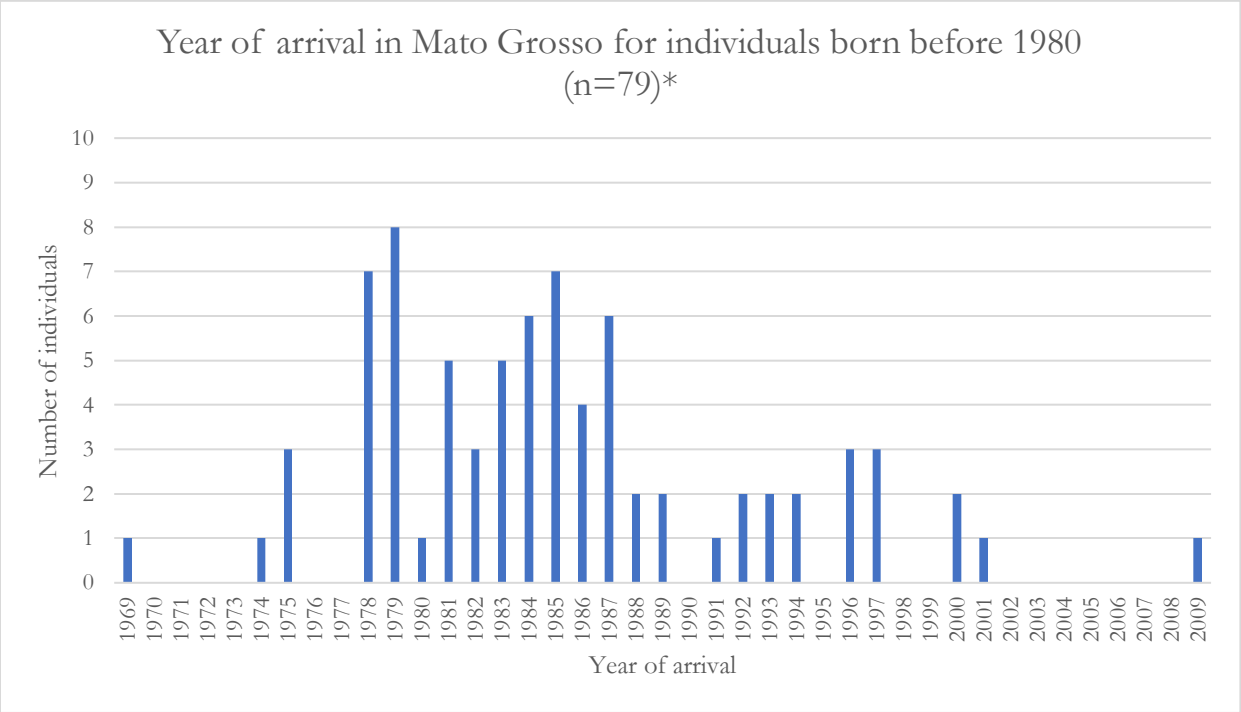


Figure 2.2. Year of arrival of individuals born before 1980. N= 79. *one individual arrived in Mato Grosso in 1955 and was excluded from representation in the chart.

According to the chart representing year of arrival for individuals born before 1980, it seems difficult to say that large-scale landowners today come from a distinctive migration period in history. Rather, the chart shows a relatively balanced distribution of years of arrival among them, suggesting that the current composition of large-scale landowners in the study region was not so much influenced by the several waves of migration usually described by interviewees (notwithstanding the fact that the remainder of the sample is composed of 25 individuals who are second- or third-generation farmers).

4. THE DIVERSITY OF LAND ACCESS AND CULTIVATING THE FRONTIER

4.1. THE CONVOLUTED STORY OF LAND ACCESS

Contrary to past writings on the topic, much of the reality of how farmers accessed land during the colonization of the Amazon has been obscured by simple narratives: colonizers would either access land from a public colonization project (mostly in Pará, with a very few instances in Mato Grosso) or through the workings of *colonizadora* which were in charge of privately selling land. Using archival work, Jepson (2006a, 2006b) identified the quantity of land settled with each way: public colonization[82] only represented 1.2m ha of land along the TransAmazon highway in Pará and about 2.5m ha in Rondônia while private colonization represented 3.9m ha in Mato Grosso. This account leads one to think that private colonization, led by corporations or cooperatives from the South in Mato Grosso was the predominant form of land access. While not contesting the importance and key role of private colonization firms in the process of colonization in Mato Grosso, I will highly complicate this point by showing how *single colonizers frequently accessed various categories of land at the same time*, combining all the possibilities offered by the frontier. This contradicts several key points of the literature which assumed 1) that land provided by *colonizadoras* was the most secure; and 2) that farmers would choose the most secure land or at least prefer it. It hinders the image of "certain types of colonizers choosing or preferring certain types of land" based on their rational economic calculus. On the contrary, it shows at the least that colonizers did not dislike diversifying risks and opportunities to make profit out of agriculture.

[82] Public colonization consisted essentially of settlement projects run by INCRA which provided settlers with land, seeds, inputs, credit and legal titles. In practice, much of this assistance and land title security never materialized on the ground

The land access regimes that colonizers relied on depended on each municipality specificities, but one can distinguish five main types for the study region of the BR-163 and the Chapada dos Parecis:

(1) *Private colonizadora or cooperatives*: this was the main and often initial way these municipalities were colonized, at least for the BR-163 area. As described earlier, it consisted of firms which got area from the federal government and the state of Mato Grosso and were in charge of bringing colonizers from the South and selling them land plots. The legitimacy and legality of these practices vary greatly from one municipality to another. Among this category, one can find the colonization firms that founded some of the municipality of the study such as the Grupo Mutum, the Colonizadora Feliz, and the Colonizadora Sinop.

(2) *"Second-tier" colonizadoras*: while these colonizadoras were much less known than the ones of the category above, they nonetheless contributed to colonize large areas depending on the INTERMAT, 100km away from the federal highways. An example of this *colonizadoras* is the "Melhoramentos Tropicais" in Nova Mutum, which helped colonize large areas east of the municipality and other municipalities too.

(3) *The "corretor,"*[83] *"agrimensor"*[84] *and the secondary land market for* posse*:* much more present in the Chapada dos Parecis, a large part of land was under the status of *terras devolutas* and could be subject to *posse*. They were distributed by middle-men who either had to take a hold of large areas because of arrangements with INTERMAT or by simply claiming the *posse* on unoccupied lands and defending them by employing gunmen. Almost all the land in Chapada dos Parecis was colonized as such. In addition, many landowners accessed land by buying up the *posse*

[83] Real estate agent, generally passing an agreement with the state colonization office (INTERMAT) or federal colonization office (INCRA) to recruit colonizers from the South of Brazil and distribute large areas of land divided into small lots

[84] Real estate agent also land surveyor approved by the state who defines and delineates the land lots

that previous owners had bought. Some of these owners lived not in Mato Grosso but in other states, so farmers had to go negotiate the purchase with them in those states or in the worst-case scenario would receive an 'unfriendly' visit from the actual owners once they had done most of the job of valuing it (by clearing it).

(4) *Spontaneous colonization through posse*: throughout the Legal Amazon, colonizers would settle at the fringe of official or private colonization projects and appropriate relatively large areas of land by their own means. They needed to delineate boundaries, create or use natural landmarks (such as rivers), and if needed, defend themselves from invasions by others interested in the area. Sometimes, an area which had been thought of as available had actually been sold in the past but had remained unoccupied by its owner. In such cases, it was not rare that the owner (usually someone from the South who had never set foot on the area) would show up or send gunmen and claim their property. Farmers could either resist on their own or reach a settlement with the former owner to keep part of the property. The use of *posse* to colonize areas was not necessarily a risky business over the long term since many colonizers successfully obtained legal titles from the INCRA or INTERMAT. Nonetheless, due to the area limitations that can be subject to *posse* according to state and federal regulations (usually not overcoming 100 ha per individual), this system relied on the association of many individuals (e.g. family members, friends, acquaintances, employees) who would lend their name to the main group colonizing an area. These individuals are called "oranges" in Brazil (i.e. "*laranja"* in Portuguese), and a colonizer needs to gather dozens of them in order to settle on more than 2,000 ha of land.

(4) *Public colonization (by INCRA) and* ad hoc *colonization projects (e.g. PRODECER)*: Considered a "failure" and only present in Lucas do Rio Verde, this 240,000 ha land reform project in 1982 displaced some of the 29 colonizers who had been present there since the late 1970s (A.

U. de Oliveira 2005). The land lots were gradually bought back by some of the *posseiros* already there and by newcomers, such that I was told in the field that only 2 of the original 213 official colonizers were still producers in Lucas do Rio Verde (I interviewed one of them). By *ad hoc* projects, I refer here to a type of project only present in a few places in the Brazilian Cerrado and conducted by the Japanese International Cooperation Agency (JICA) under the PRODECER program. They had one settlement program in Lucas do Rio Verde in 1984 and another in the neighboring municipality of Tapurah. Some of the farmers interviewed in Lucas obtained land lots from this project in the mid 1980s.

4.2. LAND PURCHASE STRATEGY IN EACH MUNICIPALITY

In each municipality of the study, one or a combination of these categories of land were used by colonizers. As such, one can find numerous examples of farmers buying land lots from a *colonizadora*, buying additional lands from a third party ("second-hand" sale), and appropriating some other land by *posse*.

> *He [i.e. the father of the interviewee] did not use the services of a* colonizadora*, there were many landowners who looked for people from the South to purchase their land" [ITW n°031]*

Equally important, not all the settlers of private colonization projects (category 1) were necessarily more capitalized than other settlers following different colonization paths. There are more than a few instances where the wealthiest farmers chose to colonize areas of *terras devolutas* through *posse*.

In the BR-163 (Alto Teles Pires) region:

- Nova Mutum: several colonizadoras contributed to the colonization of Nova Mutum. Throughout the interviews, I could identify three main actors: the Grupo Mutum, the Melhoramentos Tropicais, and the "Berre Fertil" (name to be confirmed). The Grupo Mutum was the initial colonization project of an area of 169,000 ha around the BR-163 highway, partly legally obtained and partly illegally occupied. The Grupo Mutum still has a very large property in the area and serves also as a real estate agency in the municipality.
- Lucas do Rio Verde: this area of the BR-163, in between Nova mutum and Sorriso (both colonized by *colonizadoras*) was first colonized by *posseiros*. Shortly after, in 1982, the federal government chose this location for a land reform project (*assentamento*) and then the PRODECER created new land lots to be occupied in 1984 (see ITW n°017). I was unable to denote the presence of any *colonizadora* in this area.
- Sorriso: although not the first one to be present, and not the original founder of the city, it was mostly through the activities of the Colonizadora Feliz that this area was settled. Given the limited geographical scope of the *colonizadora*, other colonizers bought land from "second-hand" landowners who had land under *posse* or from *corretores* and *agrimensor*es who had taken hold of areas of *posse* (e.g. ITW n°031 told me that were many people selling land under *posse* in Sorriso at early as in the end of the 1970s). Some used the services of the Colonizadora Tapurah for areas west of Sorriso [ITW n°065]
- Sinop: the Colonizadora Sinop is one of the oldest *colonizadora* projects in northern Mato Grosso and was responsible for creating several settlement projects in large land areas (*glebas*, in Portuguese). It thus settled the entire municipality of Sinop, as well as parts of the municipalities of Cláudia and Santa Carmem.

In the Chapada dos Parecis, the story unfolds radically differently:

- Campo Novo do Parecis: initially settled by three families of farmers who occupied land under *posse*, the city was founded after a few of them donated a small part of their land to build the first buildings. There were no *colonizadora* in the area, but *corretores* and *agrimensores* selling *posse* or second-hand properties were common in the area. The areas were regularized with a land title either by the INCRA or the INTERMAT if they were further away than 100km of the highway.
- Sapezal & Campos de Júlio: these areas were settled by a couple of *corretores* including Masutti (which later gave its name to a very large agribusiness group in the area of Campos de Júlio). In both municipalities, each *agrimensor* had hundreds of thousands of hectares to distribute and were recruiting potential colonizers in and around their hometown in Southern Brazil. During the interview with one of their sons, I learned that only two *corretores* settled almost the whole area of Campos de Júlio and Sapezal. Some authors mention the existence of the colonizadora Joaçaba in Sapezal, but I never heard of it in all my interviews (Lucidio 2017). This may have been the name of the firm used by *corretores* or, as in other municipalities, it was only responsible for colonizing part of the municipality.

The type of access regimes could or could not be associated with tenure security. For instance, it seems that most farmers who accessed land through Grupo Mutum had secure land titles, even those with *posse* in Mutum (see ITW n°022). On the contrary, in Sorriso, the ones who bought

from Colonizadora Feliz probably had secure land titles at the beginning but conveyed their frustration since many of their land titles are still questioned. The titles allocated by the *colonizadora* helped them to access credit at the Banco do Brasil, but it did not prevent them from being challenged in courts by former "owners." This happened fairly often due to the fact that the Colonizadora Feliz did encroach upon an area owned by an American family (the Zanini family) and *colonizadoras* in general had sometimes sold the same land plot twice when they observed that the first buyers were not migrating or paying for the lots. In those cases, some farmers even told me that it would have been far more secure to colonize areas using the *posse* (e.g. ITW n°032, n°031). The farmer n°031, for instance, bought a *posse* in Sorriso in 1979 and had the title regularized by INCRA as soon as 1983. Interviewee n°065, also in Sorriso, willingly chose not to operate with land titles first, seeking a land title only after his operations stabilized. This shows that farmers sometimes chose to have tenure insecurity.

On the other hand, *agrimensores* or *corretores* could have good or bad titles to sell. In some cases, some had INCRA-approved titles, but in other cases, they were selling fraudulent ones (e.g. case of a fraudulent *corretor* in ITW n°041; e.g. case of a "legal" *corretor* in ITW n°042). This uncovers another meaning of land tenure security which is less about actually having a regular land title, but rather having legitimacy in the title. Fraudulent or not, what mattered most was that the title allowed colonizers to access rural credit by providing a land title to the bank as a collateral. For instance, in Sinop, the colonizadora sold many fraudulent titles but, according to an interviewee, the bank never questioned those titles perhaps because of the strong legitimacy of the colonizadora in the area (see ITW n°051).

Another extremely important point was that those purchases were rarely individual: they were joint purchases. Quite often the members of a same family, or even friends from the same municipality of origin, would join in to purchase a land plot (each owning a third or quarter of the plot with unequal shares based on purchasing capabilities) because they lacked capital. This explains why, once the frontier got consolidated, many farms were divided up to facilitate family succession among initial partners' families who faced the prospect of dividing their own share into several other shares for their sons. In that sense, the capitalization of those farmers has certainly been overestimated in historical accounts. Since a land lot purchase had to bear just one name, it probably conveyed the idea that a single individual could buy a large amount of land as compared to what they owned in the South. It obscures the subsequent story that, in the decade after their installation, many estates had to be divided up so that each family member could administer the farm based on the nuclear family and seek new strategies of land purchase to ensure that their sons would be able to carry on agriculture in the area. It is therefore common to have farmers who bought or accumulated 5,000+ ha in the 1980s-1990s and who today own just around 2,000 ha because they divided the land between family members and business partners.

One conclusion about how colonizers seem to have diversified their land access is that they might be diversifying risk. The literature usually has one-way explanations of land access based on colonizers following rational optimization strategies and thus demanding property based on the degree of tenure security (e.g. Alston, Libecap, and Mueller 1999). In other explanations, colonizers would prefer to access land through cooperatives/colonizing firms since they provide them with land tenure security, hence reducing transaction costs (e.g. Jepson 2006a, 2006b). The review of the life trajectories of the farmers in the study show a different picture:

(1) Colonizers often mixed different types of land property category (colonizer or posse), and land security might have depended more on the location than anything else (e.g. Nova Mutum versus the rest of the BR-163 area, or the Chapada dos Parecis);

(2) Colonizing firms (*colonizadoras*) provided different degrees of tenure security instead of a uniform "quality" of land titles across Mato Grosso. Although they undoubtedly offered farmers the possibility to demand rural credit at the bank, the fraudulent titles granted by some may have caused some economic losses due to informal or legal settlements between competing claimants.

As such, I do not consider that the main role of colonizadoras (i.e. providing land titles allowing access to credit) is completely called into question. However, one may consider that the absence of colonizadoras did not impede areas such as Lucas do Rio Verde (i.e. colonized mainly by posse and fairly stable in terms of land security) and the whole Chapada dos Parecis area to develop agriculture in similar ways to municipalities of the BR-163 which had such organizations (i.e. Nova Mutum, Sorriso, Sinop, etc.). This begs the question of whether the colonizadoras model really was the key difference for explaining the development of the two areas. Some authors have argued that the particular model of the colonizadora and that of the southern-based cooperatives helped reduce transaction costs associated with frontier agriculture (Jepson 2006a, 2006b). To be sure, farmers rapidly organized their own cooperatives in the Chapada dos Parecis too, but it is not the cooperatives that brought them there. If this model was not as critical in the Chapada dos Parecis, then the most common factor to both locations of the study area is the type of colonizers who migrated there. Whether the colonization by private firms or cooperatives was the key factor of the agricultural development of the region is thus still opened to debate.

5. THE PERIOD OF SETTLEMENT AND AGRICULTURAL IMPROVEMENTS

5.1. SETTLEMENT OF COLONIZERS, LAND CLEARING, AND CROP CULTIVATION VARIETIES AND TECHNIQUES

After[85] the land purchase was decided by the family, the colonizers migrated from the south of Brazil to Mato Grosso by bus or by car. After a long journey up to Cuiabá, they still had to travel several days to pass through the municipalities of Diamantino or Rosário Oeste (where the closest banks were at the time) and reach their respective property locations on the BR-163 or on the Chapada dos Parecis. Many, however, did not bring the whole family (wife and underaged kids) until they had established a settlement, a camping ground or a wooden house, and had done the first clearings. Several interviewees shared the fact that it had been emotionally painful for them to leave the South, and the part of the family that stayed there had been reluctant to let them go. The spouses were also reluctant to join their husbands as it would mean the loss of their social network and living in relative isolation for years.

The men would usually first go together to clear the initial plots and start agriculture. There would be groups of fathers, uncles, brothers, cousins, and friends who would join in the effort to clear up land. When the family joined from the start, wives would also join in the clearing effort, working long days. More capitalized farmers were able to bring employees from the south with them to help in the clearing, and in some cases simply left them there to do all the bulk of the work (ITW n°31).

[85] This part only briefly touches upon the land clearing patterns of the colonizers because Chapter 4 is an in-depth examination of that particular aspect

Once the land was cleared, the pioneers of these two frontiers would grow rice, a commodity adapted to Cerrado soils as it "*requires little inputs, tolerates the Cerrado soil's aluminum toxicity, and demands little phosphorous*" (Jepson 2006b: 299-300). Nonetheless, yields would drop after just 2 years and in the third year, it was not worthwhile to plant rice anymore. As a result, a large share of the pioneers arriving in the late 1970s gave up and returned to the South. By that time, soybean cultivation was entering the Cerrado thanks to the joint efforts of American-led research institutes and EMBRAPA. In the 1980s, a few farmers in the region were thus testing soybean varieties. An example of one of these farms is the famous *Fazenda do Japonés* in Lucas do Rio Verde, named as such because a Brazilian of Japanese origin named Munefume Matsubara was the owner. Colonizadoras too were making a constant effort to test soybean varieties because they knew their capacity to attract colonizers from the south would depend upon the success of soybeans. More importantly, soybeans were critical to prove the region's agricultural potential and convince the national bank, the Banco do Brasil, to allocate rural credit to farmers of the region.

To this end, the story of the original colonizadora of Sorriso (which is not the Colonizadora Feliz) told by one of its founder (ITW n°022) and confirmed by other interviews (e.g. ITW n°029) is informative. Created in 1976 by an agronomist born and trained in Santa Catarina, the colonizadora tested 50 different crop varieties in conjunction with EMBRAPA. This interviewee told me that in spite of those efforts, agronomists affiliated with the Banco do Brasil and in charge of assessing the agronomic potential for allowing rural credit were hard to convince at first. Conducting such tests and generating data about the yields obtained helped convince the bank's agronomists to authorize rural credit in the area, based on funds made available by the POLOCENTRO program.

Hence, in all the municipalities of this study, the farmers who successfully went through the rice monoculture period (around 1977-1983[86]) only began cultivating soybean in 1981-1982. From that moment on, the clearing pattern started to differ slightly. Farmers would clear the native vegetation and plant rice for two years to prepare the soil for receiving soybeans in the third year. Rice therefore became a crop for preparing the soils more than anything else. Farmers planted soybeans around the end of October, when the rains were falling consistently, and harvested in March or April. During the 1980s, soybean yields gradually increased following a conventional planting method, as farmers got to better know the region's characteristics (1983-1990). At that time, minus the appearance of a fungus[87] which caused a crisis around 1986-1988, there were so few pests that farmers could plant soybeans and leave them to grow before harvest while "going to the beach" in the South in the meantime. Farmers were earning more money with the valuation of land than the actual harvests, as the pioneers bought land when "a hectare was worth a cigarette pack," an interviewee mentioned,[88] or a land lot (~50ha) costed the price of a bicycle or a bus ticket back to the South (ITW n°018). As many failed, others were buying up their land in a spree and making good earnings. Since the 1980s was a highly inflationary period in Brazil, farmers had few options for spending the harvest gains: (1) spend it immediately on food and goods; (2) place the money in a savings account indexed on inflation; (3) invest the money by purchasing new land. At the time, the preferred strategy was to buy new land, but it is important to consider the inflation factor because most land transactions were carried out by exchanging soybean bags,[89] a "currency" which was less subject to inflation than actual money.

[86] The delineation of the rice monoculture period and subsequent period are made based on the study interviews as well as a complementary interview with an agronomist and farmer.
[87] *Diaporthe phaseolorum* called "cancro da haste" in Portuguese.
[88] Complementary interview mentioned in footnote 10
[89] It is still the case today in many land transactions

In the following period (1990-1995), farmers conducted a "minimum cultivation" model for soybeans, in the sense that very few resources were invested in soil quality. They nonetheless started to plant millet (*milheto*) as a cover crop in the inter-season to improve the soils and their yields. The straw generated by the millet helped reduce erosion, but there was not enough to efficiently implement no till techniques. During that period, the average productivity neared 60 soybean bags (*sacas*) per hectare. Starting around 1996, farmers began a two-harvest cultivation system based on soybean and corn. Having a second commercial crop to grow within the same year incentivized them to find soybean varieties with faster germination periods, so that they could fit both crops within the same rainy season. They would try to plant soybean early (today they plant in mid-September as opposed to the end of October in the 1980s-1990s) to allow for planting corn while the rains are still abundant in February and before their end in April. As a result, farmers "sacrificed" increases in soybean productivity (which would have occurred through better varieties with long germination period) and instead managed to maintain productivity but during a much shorter growing period.

The large quantity of straw generated by corn as compared to millet helped farmers to adopt no till practices. This practice is based on three principles (1) no tilling of the land to prepare the soil for planting; (2) the generation of straw with a cover crop in the interseason; and (3) the rotation of crops. The adoption of this practice in Mato Grosso was incomplete because only two of three principles (principles 1 and 2) were implemented, it is thus referred to as "direct seeding over straw" ("*plantio direto na palha*") by agronomists. This practice brought about several environmental and production benefits as it helped farmers to improve soil quality and conserve

water in the soil (Arvor et al. 2012) . The farmers slowly took up this practice over 20 years with a peak in adoption around 1996 (see Chapter 4), but all of them adopted it eventually. Explanations about exactly why producers adopted this practice can be debated but no such debate exist among farmers: they adopted it to save on gas, machine, and labor costs at a time where the economic viability of farming in the two study regions was complicated. Although it had that beneficial impact, adopting no-till practices was not so much about taking care of soil quality. Hence, it is no surprise that many farmers consider the adoption of this practice as no less than the "salvation of Mato Grosso" (ITW n°007).

5.2. LAND CONSOLIDATION AND TURNOVER

The examination of land purchase patterns reveals no dominant strategy or preferred way by which colonizers consolidate their land estate. Rather, we can distinguish three main options that could be used in combination depending on individual or family expansion strategies. The first was a consolidation strategy and consisted of buying land plots around the initial purchase as neighbors fail or abandon their land. Most frontiers were places of consistent turnover as colonizers arrived, gave it a try, and left or moved around if they did not succeed on the first land plot they had. Following this evolution, the "successful" farmer could buy up those lands, when this did not involve violence or complex "land grabbing" schemes as in other places in the Amazon (Campbell 2015).

The second strategy followed the same logic but instead of buying around the initial land plot, the colonizers was buying other properties within the same municipality. Following the opportunity, the landowner's objective may have been to sell land that is remotely connected to

infrastructures and buy land the closest possible to the road, as this influences the profitability of a farm. Those landowners today often have three or four non-contiguous properties within the municipality, which does not ease the organization of agricultural production due to the increased distance to travel in between properties. Finally, the third strategy was the most "aggressive" one from a business standpoint, and referred to landowners who bought relatively large land plots outside their municipality of residence. Operating by "jumps," they sold their initial land plot in one of the municipalities of the BR-163 or Chapada dos Parecis and bought another bigger property in one of the neighboring municipalities that were still frontiers in the 1990s and 2000s (e.g. Vera, Feliz Natal, Tapurah, etc.). The idea was always to 'multiply' the original area of land by a factor of 2 to 4, some selling 5,000ha of land to buy 20,000ha in new frontiers. As one of the interviewee explained:

> *"I have always bought and sold land in Mutum, Sorriso, Sinop, Diamantino. For instance, I sold 3,000 hectares in Mutum to buy land in Sinop which is less far from the road. It is easier to manage the farm as such" [ITW n°018]*

Others decided to keep their initial property and go invest in land even farther away, in municipalities in the northern part of Mato Grosso (often former and degraded pastures) or in other states like those of the MATOPIBA area and Roraima.

Land purchases were not a constant endeavor and depend on the economic conditions of the landowner or their family at a given time. Many interviewees did not buy any additional land from the time they arrived in the municipality until the late 1990s early 2000s, simply because they did not have the means or the need to do so. Farming in the area during the 1980-2005 period was highly cyclical, despite improvements in the second half of the 1990s after economic stabilization. In that sense, the economic context was not always conducive to expansion, especially in the

1990s, as these frontiers were consolidating with the increase in soybean productivity. As a consequence of this, the attractiveness of investing earnings in new land decreased while investing in the productive use of land became the most profitable economic strategy (Becker 2005). Other landowners continuously invested in land and never stopped, giving priority to the land market to increase their wealth. Today land prices are prohibitive for most farmers, even the most capitalized. Thus, many have changed their strategy and prefer to invest their economic surpluses in the "verticalization" of production processes (machines, processes, equipment, storage facility, skilled labor, etc.).

6. LARGE-SCALE FARMERS TODAY: UNDERGOING FAMILY TRANSITION

To paint a picture of large-scale farmers today, one must consider both the stories of pioneers and colonizers as well as those of their sons and daughters taking up the activity and representing the second- and third-generation of farmers in this area of Mato Grosso. In this section, I present a snapshot of the large-scale soybean producers included in the sample at the time of the study (i.e. 2017). It reflects the activities and economic status reached by colonizers of successive migration waves and discusses the socio-economic characteristics of the farmers in terms of education, etc.

6.1. SOCIO-ECONOMIC CHARACTERISTICS

The examination of the education record of farmers demonstrate that they were more educated than most colonizers of the Amazon. Slightly more than half of the sample of 104 individuals has received a higher education or technical training (58 individuals) while the other 'half' has either just completed high school or had to abandon schooling far earlier than this (46 individuals), with some individuals leaving school at just 12 years old. Of the trained individuals (n=58), 15

underwent 2-year technical trainings in agriculture or in accounting. The remaining 44 individuals went through the full 5-year Brazilian higher education training in fields as diverse as law, accounting, veterinary studies, dentistry, civil or mechanical engineering, and agronomy. Agronomy is the most prevalent training with 19 individuals trained as agronomists. In spite of a good educational record, it is important to note first that several of the interviewees pointed out that they had been the only one of their family to pursue higher education. Second, higher education background tends to be associated with younger producers. Second- and third-generation producers have been sent off by their parents to universities in the South of Brazil (where they have relatives) or in one of the many universities that have opened in several towns of the BR-163 or near the Chapada dos Parecis (in Tangará da Serra or in Vilhena, in Rondônia).

Except 8 individuals who are still single or have divorced (or their spouses have passed away), all soybean producers in the sample are currently married. The demographic transition in one generation of farmers is stunning, as early colonizers were often born in families of about 10 brothers and sisters but only had – in turn – on average 2 children.

6.2. PROPERTY OWNERSHIP AND PROPERTY CHARACTERISTICS

Most farmers in the sample control (own or rent) an area between 5,000 and 10,000 ha, and still directly operate their farms, at least partially. Large-scale soybean producers often operate multiple properties in conjunction with farm managers they hire to oversee the operations on each farm, and some even combine land ownership and rentals. Overall, summing up both the area owned and rented, the soybean producers included in the sample control a geographical area equivalent to 1,076,152 ha (972,977 ha owned and 103,495 ha rented).

Area (in hectares: ha)	Total area owned	Total area rented	Total area controlled
No area (0ha)	2	73	0
< 2,000ha	13	12	6
2,000 – 5,000 ha	32	6	36
5,000 – 10,000 ha	31	4	32
10,000 – 20,000 ha	12	2	13
> 20,000 ha	12	1	14
No information	2	6	3
TOTAL	**104**	**104**	**104**

Table 2.11. Sample breakdown as per area owned, rented, and controlled (i.e. adding owned and rented areas). Note: Farmers were asked both the area under their ownership and the area they rent to third parties and on which they plant. Hence, "total area controlled" refers to the sum of the total area owned and rented. 2 farmers did not own any land but rent everything they have, and 73 farmers did not rent any land.

About two fifth of the sample (42 individuals) control areas of up to 5,000 ha **(See Table 2.5.1)**. 6 individuals interviewed had less than 2,000 ha because, although they were supposed to own over 2,000 ha, it turned out that the information provided by the local sindicato was not always accurate or up-to-date. Some of them had either gone bankrupt and had to sell part of the property, or had recently undergone a division of the family property, reducing the total amount owned by each individual member. Another issue is that *sindicatos* do not always have accurate information because a same farmer can be affiliated to several *sindicatos* through properties located in different municipalities.[90] Around a third of the sample (32 individuals) is comprised of producers who control between 5,000 and 10,000 ha. The classic profile of such farmers is to have one or two large properties and rent an additional area to a neighbor or in another municipality. Finally, a quarter of the sample is composed of the largest landowners, controlling more than 10,000 ha, 14 of which having more than 20,000 ha. Some of them are former family groups consolidated into corporate groups with large-scale operations, having their own silos, truck transport company, etc.

[90] The sampling relied on contact lists provided to me by local *sindicatos* according to the criteria of only including soybean producers who owned more than 2,000 ha. Local *sindicatos* do not always have accurate information on the quantity of land owned by affiliated producers since the conditions of affiliation vary from one *sindicato* to the other. In order to get affiliated to the *sindicato* in Lucas do Rio Verde for instance, producers pay a fee based on the number of hectares they plant. They therefore have an incentive to under-declare the area they own. Other landowners may operate in several municipalities and area affiliated to multiple *sindicatos*.

They are large enough to directly negotiate inputs such seeds, fertilizers, and pesticides with the multinationals producing them instead of negotiating with a local *revenda*. Also, it is not rare that these soybean producers rent 10,000 ha or more to other farmers in distant frontiers of Mato Grosso, usually degraded pastures that cattle-ranchers want to rent out to convert into soybean fields.

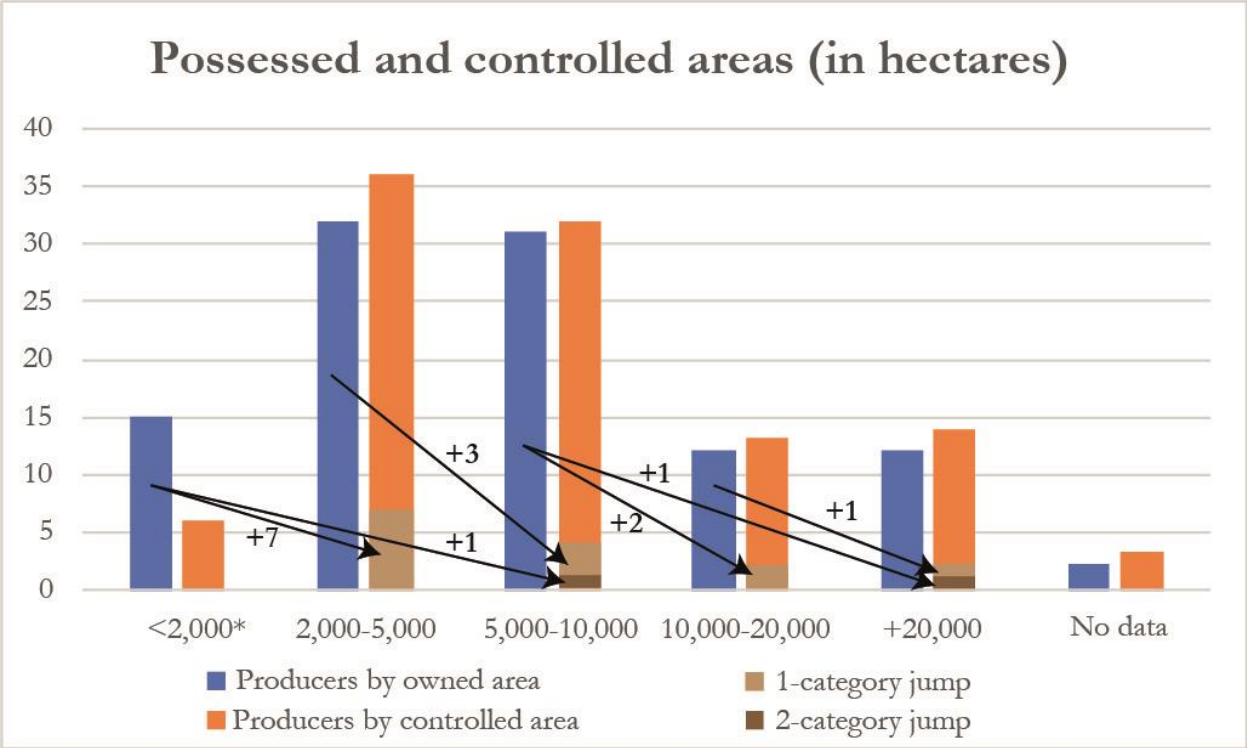


Figure 2.3. Land size category jump associated with renting land. "Controlled" here should be understood as the area owned and the area rented by one producer (and not hidden ownership of rural properties). Note: Producers in this chart are classified by area owned and area controlled. The way to interpret the chart is the following: some of the owners represented by the blue bars would be classified in a higher category if we accounted for the additional area they own. Once accounting for the rental area, some of the owners jump one or two categories higher. Example: A landowner owns 1,800 ha and rents 3,000 ha. She is classified an owner (blue bar) in the "< 2,000ha" category and as someone who controls land (orange bar) in the "2,000-5,000ha" category. *There are 15 producers under 2,000 ha in this chart because we account for the two producers who own 0 hectares. One of them own 0 hectares but rents 8,000+ hectares. Figure prepared with the help of Dr. François-Michel Le Tourneau.

Interestingly, 31 landowners rent land (among which only one rents land and does not own a property), proving the development of land leasing in these soybean production areas. At a time where purchasing new areas is expensive, leasing is a common way to expand. Recently, several cattle-ranchers decided to sell or rent out their degraded pastures to soybean farmers who restored

their fertility and expanded soybean cultivation on them. In addition, several farmers who did not find someone to succeed them decided to rent out their land instead of selling it. Because of this, some landowners actually control areas far greater than previously assumed (See Chart 4.2). For instance, one of the producers interviewed (ITW n°024) only owned 8,000 ha but rented out 25,000 ha to third parties, thus controlling an area of 33,000ha.

Larger farmers who both own and rented over 10,000+ ha tended to be more likely to follow such strategy. They demonstrated a capacity to organize advanced agricultural activities in areas that are former cattle-ranching frontiers, and are still actively clearing forests. At the time of my fieldwork in 2017, they were purchasing or renting land in municipalities like Ipiranga do Norte, Tapurah, Brasnorte, Tabaporã, União do Sul, or Nova Ubiratã. Nonetheless, they were also attracted by opportunities to convert degraded pastures into soybean and corn fields in old municipalities south of the study area, like Diamantino, a former diamond mining town and one of the key locations in the early stages of colonization of this area. As a result, this farmer significantly, the area under their control. The **Figure 2.3** summarizes how producers "jump" from one land size category to another if we start considering the rented areas. The total area rented by farmers in the sample represented an additional 103,175 ha to the 972,977 ha producers owned.

Generally speaking, these properties are located within the municipality of residence of the farmers (one of the 7 municipalities covered in the study). The municipalities of the BR-163 and Chapada dos Parecis now boast a broad set of infrastructures (e.g. schools, hospitals, universities) such that it is not rare to see producers who cultivate in neighboring municipalities residing there. It is especially the case for Sinop, which has grown as a "capital" of northern Mato Grosso and is

the crossroads of many economic activities in the region. Some of the farmers who bought larger properties in neighboring municipalities, which were still agricultural frontiers in the 2000s (e.g. Vera, Tapturah), still live in the same municipality. They therefore did not dislocate themselves following a land purchase like colonizers did in the past, even though they no longer own land in the municipality where they reside.

6.3. A PROFILE OF AGRICULTURAL ACTIVITIES IN THE BR-163 AND THE CHAPADA DOS PARECIS

The overwhelming majority of soybean producers in the area use the double-cropping system based on soybean and corn or soybean and cotton (VanWey et al. 2013; Arvor et al. 2012). The soybean/corn system emerged in 1996 in the region. Producers using this system tend to plant soybeans as early as possible in September as the first rains arrive, and harvest in late-January or February. As they harvest soybeans, they immediately plant corn. Farmers commonly report that sometimes the soybean harvesting machine is followed directly by a corn planting machine. They then harvest corn during May and June, depending on when the planting occurred as delays may have occurred because of insufficient rains in September or abundant rain (impeding the harvest of soybeans which requires dry weather) in January-February.

In total, the farmers interviewed planted 334,356 ha of soybean and 328,236 ha of corn in the surveyed properties[91] for the 2016/2017 planting season.[92] Only 9 farmers reported planting cotton,

[91] As explained in the methodological details, I asked the interviewed producers to only report information on their main property which had to fulfill one or more of the following three criteria: (1) oldest property owned by the producer in the area; (2) largest property owned by the farmer; (3) property located in the municipality where the farmer lived and was interviewed

[92] Unless otherwise specified, all planted area data mentioned in this chapter is for the 2016/2017 planting season

though some interviewees did not report their planted area broken down by each crop. This is somewhat consistent with observation in the fields, according to which only the most capitalized farmers produce cotton because it demands investments in specific machines and many inputs. Cotton producers usually own over 10,000ha of land although I have witnessed one producer who rented all the land he planted and was cultivating about 8,000ha of cotton. Although the soybean/cotton system was 'popular' in the 2000s, many producers who went bankrupt during the 2004/2005 agricultural crisis in Mato Grosso have since withdrawn from it.

Figure 2.4. Soybean harvest (February) in Nova Mutum. Picture taken by the author (February 2017)

In addition, some farmers attempt to do a third harvest by using pivot irrigation and planting beans. In Mato Grosso, producers plant beans either as a second (taking advantage of rains) or third harvest (using pivot) depending on their economic strategy (Note: some farmers seem to not even understand why other farmers plant corn in second harvest as they argue doing so results in losing money, e.g. ITW n°051). This trend is nonetheless limited as only 17 producers declared

using an irrigation system while some have expressed concern that widespread conversion to this type of farming would result in destroying water resources. Given the fact that local farms are usually located next to rivers and are large enough to encompass multiple springs the development of pivot irrigation for a third harvest cycle is a real possibility in the future.

Campo Novo do Parecis presents a regional specificity regarding crop varieties. It is the only municipality where one can find three other crops being cultivated in second-harvest after soybean: sugarcane, "popcorn" corn, and sunflowers. The municipality has an unparalleled history of cooperatives and pioneering among its farmers which explains why producers there were able to plant different varieties of crops. Very early in the story of the municipality, in the 1980s, a few of the initial settlers got together and founded a membership-based sugarcane processing factory. Being membership-based means only farmer-members can cultivate sugarcane since others would lose all their crops because there are no other destinations for the crop in the area. The story for the "popcorn" corn and sunflower is different and is due mainly to one pioneering farmer, trained as an agronomist, who performed tests for these crops and proceeded to convince others to adopt the same system. As a result, the farmers included in this survey planted about 7,200 ha of "popcorn" corn, and today Campo Novo produces more than half of the total amount of "popcorn" corn processed in Brazil. These farmers also planted 5,610 ha of sunflower, although sunflower is on the decline in the municipality.

Figure 2.5. Corn field in Campo Novo do Parecis. Picture taken by the author (June 2016)

Besides the main crops, farmers are now diversifying crops and activities on their properties. Non-common crops include sorghum, millet, "milho branco," crotalaria, estilosante, etc. They use these crops either as cover crops or for seedling production. They use them as cover crops in the interseason (after the second corn harvest), as a crop rotation system right after soybean cultivation (as a "succession" crop), or for a whole 1- or 2- year cycle (as a real rotation crop) to help restore the soil fertility and fight against a soil disease called "nematoide." A small number of farmers (15 to be exact[93]) combine cattle-ranching activities with agriculture following an integrated crop-livestock system developed by EMBRAPA. This system consists of growing pastures (using the variety *brachiaria*) on the same area where fields of second-harvest corn are growing. Once the

[93] See Chapter 6 for more data on 'good' agricultural practices

corn is harvested, what is left is a pasture that can be used for 3 to 4 months by cattle which, in the meantime, had lived in "confining" spaces. The goal of such a system is to reduce farmers' vulnerability to commodity price variation by adding one more source of income (i.e. cattle), the price of which may or may not evolve in the same direction as corn and soybeans. 11 farmers carry out cattle-ranching activities independently from their crop cultivation activities and they may be involved at different stages of the cattle-ranching value chain.

Recently, some municipalities have innovated beyond agricultural activities. Sorriso is currently leading a new trend of fish ponds, taking advantage of the abundant water resources available to farmers on their property. Since the beginning of the 2010s, the municipality has seen a growing interest from farmers for such a type of activity and it now represents one of the significant economic activities of the municipality. Another significant advance to find new economic opportunities for producers can be found in Lucas do Rio Verde, which is now creating a factory processing corn to manufacture ethanol with the idea of aggregating more value at a local scale.

Figure 2.6. Cotton field in Campo Novo do Parecis. Picture taken by the author (June 2016)

6.4. FUNDING THE HARVEST: ECONOMIC CRISES AND THE CHANGING LANDSCAPE OF FUNDING SOURCES

The intensive agricultural system (and associated activities) along the BR-163 and the Chapada dos Parecis would probably not exist if it was not for a strong and diverse funding infrastructure. This diversity helped (some) farmers go through the successive economic crises experienced by the agricultural sector in the Legal Amazon since the colonization times of the 1970s and 1980s, and by Brazil as a whole. Farmers can rely on three main types of funding depending on their financial history and current preferences:

(1) Self-funding

(2) Banks (public and private)

(3) Private companies (*revendas* or multinationals)

Not every source of funding was available throughout the history of farming in the area. I will therefore give a description of funding sources following a chronological order, which will help explain the evolution of the funding structure of soybean producers.

6.4.1. Funding throughout the colonization period

When smallholder farmers arrived in Mato Grosso at the end of the 1970s, they were highly dependent on their own funding and that of large-scale public programs supporting the colonization of the Legal Amazon and the Center-West of Brazil. The main programs at the time were POLAMAZONIA and POLOCENTRO, whose funds were disbursed by the SUDAM and the SUDECO. Both programs had the broad objective of supporting colonization and provided funds for infrastructure building (roads, telecommunications, etc.) while at the same time providing colonizers with funding for purchasing land, equipment, and inputs. In the study area, none of the producers reported having received any funding for purchasing land. It seems that the incentives for buying land were captured by the actual *colonizadoras* rather than individuals. The colonizadora Sinop, for instance, did receive tax exemptions (on the importation of machines and on revenues) as well as funding for a manioc processing factory from the SUDAM. Farmers in the study area did however report receiving support for buying machines.

Farmers located in the study area could *theoretically* access these two main funding programs. The scope of actuation of SUDAM was supposed to go as low as the 16th parallel in Mato Grosso (covering a good 2/3 of the state), but it does not appear that municipalities like the ones of the Chapada dos Parecis, or Nova Mutum and Lucas do Rio Verde benefitted from it (Dubreuil et al. 2009). According to Abreu (2016), the area of actuation of both institutions was circumscribed to

priority areas and, depending on the program implemented, could reach *secondary areas*. This fact that could explain why so few farmers mentioned the SUDAM and SUDECO programs during the interviews. Another explanatory factor is that all the municipalities emancipated[94] and become municipalities in the 1980s and the 1990s. As a result, a good share of the funds attributed by those programs may have been recorded and received by organizations located in the municipalities that formerly comprised them. All the study municipalities of the BR-163 and the Chapada dos Parecis region belonged to larger dismantled municipalities such as Diamantino (Nova Mutum, Lucas do Rio Verde, Sorriso, Campo Novo do Parecis, Sapezal), Chapada dos Guimarães (Sinop) and Comodoro (Campos de Júlio).

In practice, funds were allocated by local offices of the national bank Banco do Brasil or the BASA (the latter was more prevalent in forested areas starting in Sinop). At the time, the agronomists of Banco do Brasil were not fully convinced of the agronomic potential and it thus took efforts to demonstrate that the agriculture of colonizers would yield results, as I explained earlier in the chapter. Many other programs of secondary importance were created to support agriculture. One can cite, among them, the PROTERRA[95] program (for the distribution of land), the PRODEAGRO[96] program, or the POLONOROESTE[97] program in 1981 (S. de Abreu 2016). There were also other more localized programs such as the PRODECER, which was supported by the Japanese international cooperation (implemented in 1984 in Lucas do Rio Verde and other

[94] i.e. gained administrative independence as a district
[95] Program for the Redistribution of Lands (In Portuguese: Programa de Distribuição de Terras)
[96] Program for the Agro-ecological Development of Mato Grosso (In Portuguese: Programa de Desenvolvimento Agroecológico de Mato Grosso)
[97] Integrated Program for the Development of Northeast Brazil (in Portuguese: Programa Integrado de Desnevolvimento do Noroeste do Brasil)

municipalities) and had a profound impact on agriculture in the area because it provided the first crop silos and other supporting infrastructures.

In the middle of the 1980s, with the end of the military dictatorship and the restoration of a democratic regime in Brazil, the funds for these large-scale incentives program dried up, leaving colonizers in difficult economic conditions. As the status of agriculture was highly unstable in the area withone 'good' harvest year being followed by a 'bad' one, many farmers went bankrupt and had to sell or abandon their land to find good fortune somewhere else. The interviewees frequently referred to this period as particularly difficult and some reported not even being able to plant in some years between 1986 and 1994. This coincided with the generalized economic crisis of the 1980s in Brazil and the hyperinflation which was subject to several monetary plans, among which was the *Plano cruzado* in 1986.

In the late 1980s and early 1990s, farm cooperatives from the South started expanding their activities in Mato Grosso and provided a much-needed, although limited in quantity, funding to farmers in the area. These cooperatives were the C-VALE (which came to Mato Grosso in 1981), the COOPERLUCAS (which arrived in 1985), the COOPACEL in Sorriso (which arrived in 1984 [ITW n°070]) etc. In addition, local *revendas* of agricultural inputs provided funding on the basis of *pacote* (literally translated as "packages") which consisted of lending farmers inputs in exchange for a payment in soybean "bags" at the end of the harvest. The "interest rates" resulting from such dealings are usually less advantageous to farmers than the interest rate they could get from rural credit. Farmers thus tend to stay away from them, but may find themselves having no

other choice than relying on them if they reached the limit of what they can borrow at the bank (or if the bank blacklisted them due to non-repayment of previous loans).

Finally, in the mid-1990s, agribusiness multinationals started moving into the region and funding producers directly. Giants of the agribusiness like ADM, Cargill, Bunge, Louis Dreyfus Commodities (LDC), and other national companies started locating activities there mainly to purchase soybeans to export to international markets. They concentrate their purchases in large grain storage facilities along the main roads of the municipalities until trucks come to transfer them to the port of Paranaguá in the South. Similar to *revendas*, the multinationals negotiated "packages" with the farmers to trade inputs in exchange of a set number of soybean bags to be delivered at the following harvest.

The *Plano real* launched by FHC in 1994 along with the rural debt securitization (*securitização*) of 1995, which allowed the renegotiation of the acute indebtment of the farm sector, restored some stability in the Brazilian currency and greatly improved the economic situation of agriculture in Mato Grosso. The soybean producers who survived this period remained however deeply indebted and are still paying the financial 'mistakes' made during this period today.[98] This period also marked the return of public funding in Mato Grosso's agriculture, and producers were able again to rely on rural credit from Banco do Brasil more often.

[98] This period has been one of the remote cause of local and national protests when another crisis irrupting in 2004 and 2005 further degraded producers' financial situation. Two protest movements led by farmers shook the political situation. The first was the *tratorasso* led by farmers from the South and the second, more local, was referred to as the *Grito de Ipiranga* as it originated from the sindicato of Ipiranga do Norte in Mato Grosso, a municipality next to Sorriso.

Following the boom in soybean production in the area in the late 1990s, private national and international commercial banks made their arrival in Mato Grosso and sought to fund the lucrative activities of soybean producers. International banks interested in funding lucrative agricultural activities such as the Dutch Rabobank, the Spanish Santander, or the national bank Bradesco, arrived to fund the largest producers (25 interviewees are using or have used the services of Rabobank, for instance). Although they made public lines of funding available to farmers, they most notably offered to lend money in dollars for the first time, which meant (sometimes) lower interest rates than in Brazilian reais.

6.4.2. Farmers funding structure today

It is important here to distinguish the harvest cycle funding from the funding for equipment (e.g. harvesting machine). The harvest cycle funding includes all the season's costs: seeds, fertilizers, chemicals for pests and insects, labor, etc. It is generally the largest cost and has the most diverse funding structure. The funding for equipment like tractors, harvesting machines, and seed-planting machines (i.e. grain drills), and tractor pesticide spray machines comes from subsidized public credit lines. The most common form is to have a split between the part funded by the federal government and the farmer following an 80%-20% or 90%-10% ratio, with the government taking the greater financial burden.

In general, landowners borrow reais from national banks to purchase all the inputs necessary for the harvesting cycle, which means that they will need to pay a certain quantity of reais at the end of the period. However, since soybean agriculture is oriented toward exportation, all of a soybean producers' revenue is in dollars which they need to convert back to reais to pay the bills. Their

rentability model is thus very sensitive to the Brazilian reais – U.S. dollar exchange rate: they make extra gains when the exchange rate between the reais and the dollar is bad (i.e. one dollar is exchanged against many reais) and they incur extra losses when the rate is good[99] (i.e. one dollar is exchanged against few reais). When the new funding possibility of borrowing dollars through private national and international bank was offered in the 1990s, the temptation to borrow dollars (at a lower interest rate) was great. However, when the exchange rate between the Brazilian reais and the U.S. dollar degraded in 2004 (due to the appreciation of the reais), all the landowners who had borrowed in dollars had relatively less money once converted to reais, and found themselves in a difficult position to pay what they owed for the inputs.[100] As a consequence, the dollar debt was much harder to repay as well, and many went bankrupt because of this and other changing factors like the drop in soybean prices, etc. (Andréa Aguiar Azevedo 2009).

Today, farmers who successfully repaid all their loans tend to move away from banks and private funding through *revendas* or multinationals. As demonstrated in **Chart n°2.5.2,** this source of funding today represents less than half of their funding sources (although it neared 100% in the past). The most striking fact is how little they rely on multinationals even though multinationals had been instrumental in funding agriculture in the area during the 1995-2005 period. For large-scale landowners, private banks are used as frequently as public banks and represent about a third of their funding source. This distinction obscures the fact that private banks can also disburse rural credit issued from the *plano safra*, the main governmental plan allocating rural credit in Brazil. Generally speaking, when producers rely on private banks it is either to access funding in dollars

[99] On a side note, it means that soybean farmers are making a higher profit when the country's economy is not doing well, which usually means a weaker exchange rate position. For more insights, see (Hoelle and Richards n.d.)

[100] This problem has to be nuanced, however, because a lot of farmers negotiate their loans or inputs purchases not in a currency but in terms of soybean bags they will owe at the end of the harvest, including to banks.

or because they do not entertain good relations with the manager of the Banco do Brasil. Another possibility for farmers it to rely on SICREDI, a credit cooperative from the South. SICREDI has some flexibility in funding farming operations since, as a cooperative, it does not have to follow the exact same rules as a bank,though its operations are fairly similar to that of a bank.

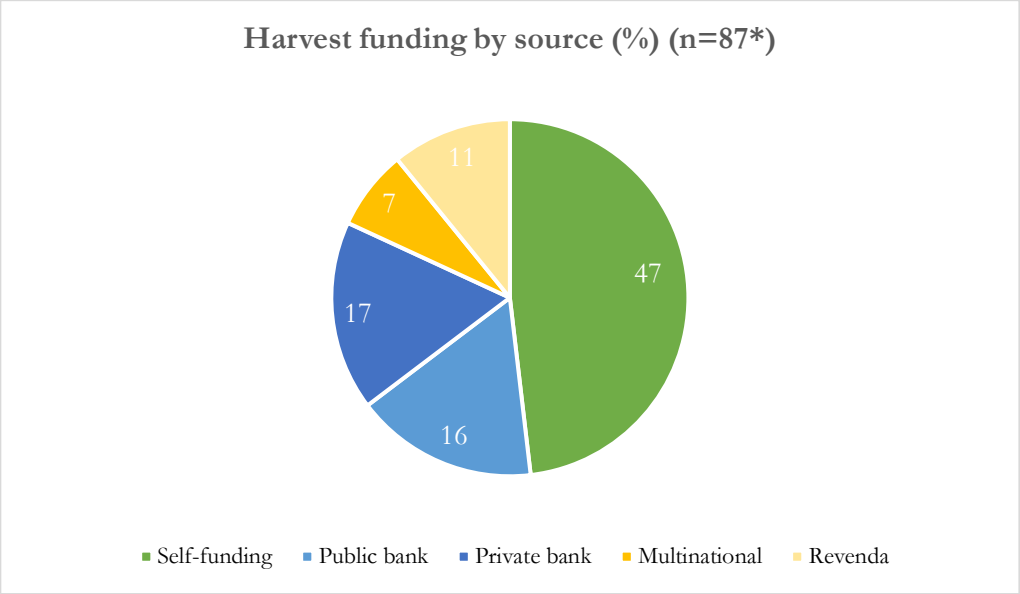


Figure 2.7. Harvest funding broken down by provider. The numbers are the average for the whole sample, hence this chart represents an "average" producer and the average share of funding coming from each source. The green color represents self-funding, the blue colors represent funding through banks and the yellow colors represent funding through non-financial private parties. *Funding data is based on the farm and not the producers (n=104) since one or more interviewees may have been working on the same farm. In total 94 different farms were included in the sample, and only 87 were presenting the degree of detail in funding structure necessary to create this chart.

The dominant source of funding for the harvest cycle of large-scale landowners is nonetheless themselves, with 47% of the harvest being self-funded. For producers between 5,000 ha and 20,000 ha, this is the dominant form of funding today. **Figure 2.7** shows the average over the sample, but in truth, more than half of the interviewees in the sample are not relying on private sources of funding such as multinationals and revendas (i.e. the median of funding through private sources is 0). The situation tends to change for producers larger than 20,000 ha because they need very large sums of money and need to take loans at the bank for this, usually in dollars. In addition, because of their size, they are able to directly negotiate lower prices of inputs with the agribusiness

multinationals producing them, therefore bypassing an essential intermediary of Mato Grosso's agriculture: the revendas. Except for those large producers, the golden standard for profitability in soybean production is to rely almost exclusively on self-funding, (and perhaps a little on credit for purchasing machines since the government offers rural credit where machine purchases are joint investments with the government financing 80% or 90% provided the farmer invests the rest).

Breaking down sources of funding by the size of area controlled by farmers allows for a finer analysis of the trends affecting each class of landowner (**See Figure 2.8**). The trend toward relying on self-funding as the basis of the profitability model is confirmed for the bulk of farmers with properties between 2,000 ha and 20,000 ha, even representing more than half of the harvest funding for properties between 10,000 ha and 20,000 ha. Smaller producers (<2,000 ha) seem to have more difficulty gathering the necessary self-capital for the harvest than larger producers. The share of self-funding also diminishes for the largest category of producers (20,000+ ha), probably because the scale of their operations demand sophisticated bank funding, which is confirmed by the share of funding coming from the banks (46.2% of their total funding).

The smaller category of large-scale producers seems to rely heavily on public bank funding, with an average 37.5%. This trend for larger producers seems to be fully inverted because they increasingly rely on private bank funding as their scale increases reaching a peak 27.8% for producers above 20,000 ha. It is not surprising each individual has a limit of (public) rural credit they can access, based on their CPF (fiscal number, in Portuguese "Cadastro de Pessoas Físicas"). Each type of rural credit line has a maximum limit, and sometimes farmers use the CPFs of other members of the family to increase the amount of money they can borrow from public funds.

However, since many farms are now organized as corporate groups, called CNPJ (fiscal number for corporate and juridical entities, in Portuguese "Cadastro Nacional de Pessoas Jurídicas"), farmers can sometimes only use one fiscal number to demand credit. Therefore, they need to look for other types of credit if they want to get funding for their activities. Another part of the reason they rely more on private banks has to do with the flexibility these institutions offer to farmers to borrow in dollars, while also maintaining the possibility of accessing (public) rural credit. At the scale of larger producers, borrowing large amounts of dollars at a lower interest rate becomes a more attractive option than relying solely on public credit.

Finally, landowners can count on an initiative by the Brazilian government as part of their climate change mitigation efforts. The MAPA established the Low Carbon Emission Agriculture plan (plano ABC), as part of the National Plan for Climate Change, a multi-billion plan (in R$) to support agricultural producers' efforts in mitigating greenhouse gas emissions (GHGs) (Gurgel and Costa 2015). The plan rests upon several elements: (1) Restoration of degraded pastures; (2) Crop-Livestock-Forestry integrated and Agro-Forestry systems; (3) No till systems; (4) Biological Nitrogen Fixation; (5) Forest plantations; (6) Animal waste treatment; (7) Climate change adaptation. This plan made several public credit lines available to producers willing to engage in GHG emissions mitigation projects but was not widely used by the producers in the sample.

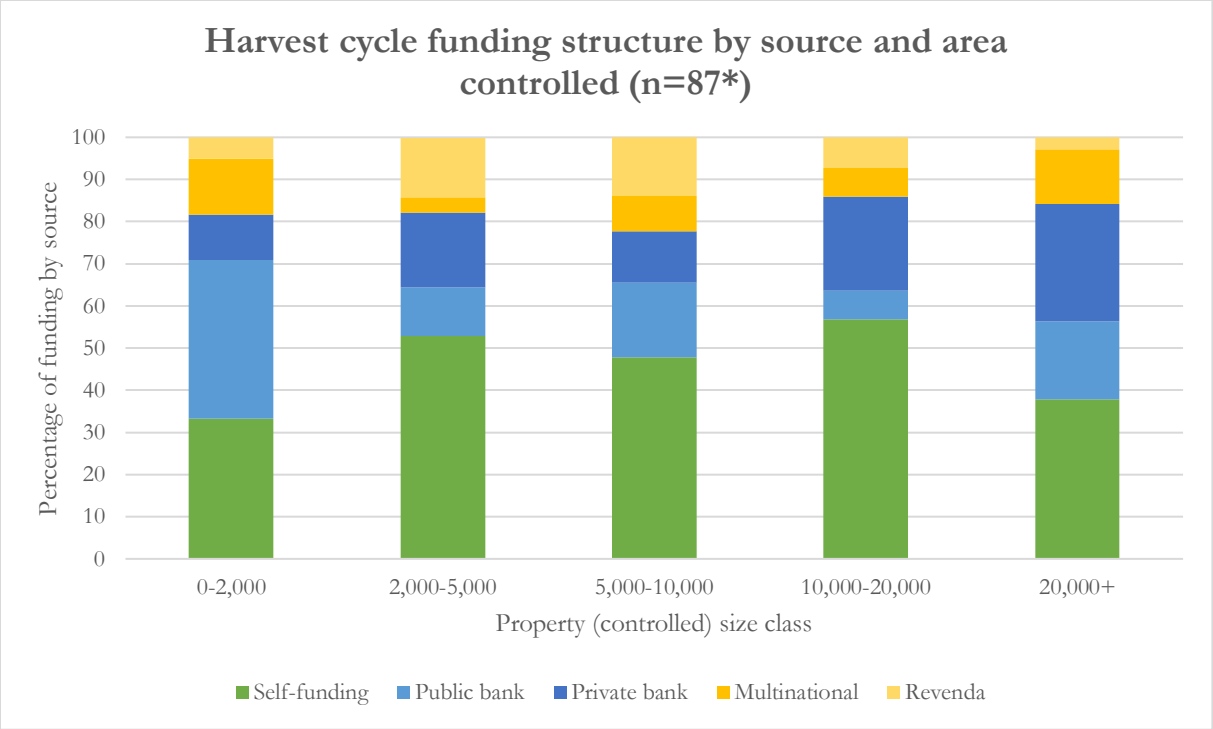


Figure 2.8. Harvest funding broken down by provider and property (controlled) size class. The green color represents self-funding, the blue colors represent funding through banks, and the yellow colors represent funding through non-financial private parties. *Funding data is based on the farm and not the producers (n=104) since one or more interviewees may have been working on the same farm. In total 94 different farms were included in the sample, and only 87 were presenting the degree of detail in funding structure necessary to create this chart.

Finally, farmers tend to rely less on private types of funding, not overcoming 20% of the total funding in any category of producers. There are subtle differences: the bulk of farmers between 2,000ha and 20,000ha rely dominantly on *revendas*. Although not advantageous because *revendas* charge higher interest rates than banks,[101] it is sometimes a good option as a complementary source of funding since the borrowing conditions are simpler because they negotiate in terms of soybean bags. When farmers have very large operations, they become able to negotiate directly with the multinationals (e.g. Syngenta, BASF, Dow Chemicals) on the amount of inputs they need instead of passing through *revendas* as an intermediary. Hence, farmers controlling areas over 20,000 ha

[101] *Revendas*, technically speaking, do not offer interest rates. Instead, they agree on an amount of soybean bags to be delivered at the end of the period by farmers. The "interest rate" I refer to here is the same one interviewees referred to: they derive a fictional "interest rate" based on comparing how much money they receive against the fixed number of soybean bags to be delivered at the end of the period.

rely on 12.9% of multinational funding and only 2.9% of *revendas* funding. It is not certain whether smaller large-scale landowners rely also on as high as 13.3% of multinational funding, as this variation may be due to the small number of observations in this category (i.e. there are only 6 farms under 2,000 ha in the sample).

6.5. PRODUCTION, FARM ORGANIZATION, AND ACCESS TO INFORMATION

Conducting operations on areas larger than 2,000 ha (or several properties) requires a robust work organizational structure. Large-scale producers operate areas that necessitate whole teams of rural workers to be managed. The interviewees included in this study were landowners selected because they are the ultimate decision-maker on every aspect of farm management. Even when the farm is now managed by the sons, it is common to hear that the father (with a strong patriarchal culture from the South) has a say in every decision if he wants to, and family disputes over agricultural production are common currency.

Nonetheless, landowners would not be able to oversee these numerous activities or travel away from Mato Grosso, if it were not for the farm managers they put on one or several of their properties. These employees oversee the daily operation of the farms "from the farm door to within the farm" following a local saying.[102] This includes preparing the soil with fertilizers, planting, spreading pesticides when necessary, and harvesting. They manage teams of machine operators and often operate one themselves. In large farms, the management of pests is left to a specialist hired for this purpose (called *pragueiro)* as it necessitates a daily examination and monitoring of the agricultural plots. They oversee the functioning of storage silos and possibly of the dryer

[102] In Portuguese: "da porteira para dentro"

(*secador*) which allow them to harvest crops with higher humidity rates than required for commercializing and transport, since most farms over 2,000 ha have such equipment. Farm managers operate in constant communication with the landowner and tend to take crop choice and planting decisions jointly.

The financial and commercial aspects of farm management are generally carried out by the landowner or one of the family members if the properties are organized in a corporate group. Those are the activities they qualify as "from the farm door to the outside."[103] Farmers in the study area commonly negotiate the purchase of inputs and their funding at the banks (or other sources) one year (sometimes two) in advance, which requires a lot of planning and anticipation of the market. Since part of the funding is negotiated with the banks and other partners in soybean bags[104] to be harvested, farmers need to constantly anticipate what the price of soybeans will be one year or two years ahead to calculate the *de facto* "interest rate" at which they borrow money.[105] Similarly, they need to anticipate the price for commercializing their crops, and it is not rare either that a farmer has already negotiated and sold the harvest of next year when you meet with him. The use of storage units has enabled farmers to take less risk when selling their crops on the spot once harvested, but it is more common today to have farmers anticipating this moment and creating *future contracts* to sell their production in anticipation at a fixed price. Without an employee specialized in such dealings, large-scale farmers rely on consulting firms for every aspect of financing and commercializing. They hire the services of consulting firms at the Chicago Board

[103] In Portuguese: "da porteira para fora"
[104] 1 soybean bag (called "saca de soja" in Portuguese) is equivalent to 60 kilograms, hence about 2.2 bushels
[105] Note: some do borrow money instead but it is hard to assess the extent to which farmers negotiate the funding of their harvest in soybean bags and money

of Trade who have their eyes on the commodities market and the most commercializing-oriented farmers may have screens in their offices showing the price of soybeans and corn at every instant.

Hiring consulting firms is just one of many ways large-scale producers access information to make strategic farm management decisions. More capitalized farmers use the services of agronomic consulting firms to decide what to plant and how to improve the quality of their soils. Since there are no extension agents in Mato Grosso, less capitalized farmers are dependent upon the 'free' advice of inputs resellers interested in promoting their products who visit farmers regularly at their farm or their office. Hence, one of the main sources of information for farmers of Mato Grosso is likely to be somewhat biased by the business interests of resellers of large agribusiness firms and chemical companies like Monsanto, BASF, Bayer, Syngenta, and so forth. Additionally, large-scale farmers consult agricultural (non-academic, save for agronomists) journals and magazines, access various agriculture-related websites, and look at recommendations available on the website of their main association APROSOJA-MT.

In many respects, large-scale soybean producers have less constraints on information access than farmers owning less than 2,000 ha in Mato Grosso. Nonetheless, a great part of accessing and exchanging information seem to be done between farmers themselves. They talk to neighbors and bounce ideas off each other whenever they have the opportunity, or while visiting in town or stopping by the local sindicato. They are also in touch through the mobile phone application Whatsapp ® and exchange news and advice. Some are so well-connected that they even have Whatsapp ® messaging groups with Blairo Maggi, the Ministry of Agriculture originally from Mato Grosso. In between harvests, they go to one of many *dias de campo* (literally translated as

"field days") organized by some national (e.g. EMBRAPA) or local (Fundação MT) research institutes or by agribusiness and chemical firms. These field days typically consist of a visit of a pilot site where various crop varieties were planted to compare their performance and have panels of experts (from academia, research institute, or business firms) on trending topics.

7. CONCLUSION: MIGRATING TO MATO GROSSO, A GAMBLE?

This chapter has helped define the general socio-ecological as well as historical context in which the two leading soybean producing regions of Mato Grosso have come to prominence, and how this was made possible through a particular social base of smallholder farmer families emigrating from the South of Brazil in successive steps.

The main chapter takeaways with respect to the history of Mato Grosso's colonization and the identity of large-scale soybean farmers can be summarized as follows:

(1) The private colonization of Mato Grosso was almost exclusively done by groups of smallholders (families or business partners), and not only individuals, from the South of Brazil who did not rely on *colonizadoras* alone but of several land access opportunities including markets for *posse*, public colonization programs (land reform and PRODECER), and so forth. Importantly, more than looking for an organization that would offer cheap land to them, farmers would pay specific attention to the presence of a social network in the area (e.g. known family or acquaintances) when deciding to settle somewhere.

(2) The importance of tenure security for frontier farming is to be significantly nuanced. Land tenure security seems to be less dependent on the presence of an organization legitimizing land titles than on the particular conditions and context of the place where

colonizers settle**.** The chapter has demonstrated that a single farmer would not mind to sometimes combine different types of land and levels of tenure security when farming on the frontier. Furthermore, several *colonizadora* offered even less tenure security than *posse* depending on the location, since they too were engaging in illegal land appropriation.

(3) The BR-163 and Chapada dos Parecis frontiers have relatively similar development levels regardless of the presence or lack thereof of key organizations reducing transaction costs of frontier agriculture. Whether *colonizadoras* and agricultural cooperatives were key, as Jepson argued, is somewhat contradicted by the virtual absence of *colonizadoras* and cooperatives in the Chapada dos Parecis when colonizers settled. This however neither means that colonizers did not organize their own cooperatives after they settled nor is contradicted by the arrival of cooperatives later on. The fact that only *corretores* and *agrimensores* were responsible for bringing colonizers from the South in the Chapada invalidates some of the conclusions made about these organizations in the BR-163 region.

(4) Large-scale soybean producers of the study area are the complex product of different socio-economic backgrounds, various waves of colonization, and adaptability to new economic and agricultural challenges. The study area has undergone several economic transformations and has faced several production challenges such that the large-scale landowners who survived during or grew stronger from this evolution present different profiles and strategies. Beyond all, all of the farmers pursued different strategies to adapt to these challenges by modernizing agricultural production.

This story is unique in a way since it was, for many, a gamble. Several of the pioneers I interviewed testified that no one wanted to settle in these areas in the late 1970s. The agricultural

potential was yet to be proven, and the overwhelming majority of southern migrants were heading farther north, beyond Sinop, attracted by the fiscal incentives and state subsidies provided in forested areas of Mato Grosso. Despite discouragements, numerous difficulties, and early disappointments, these farmers believed that the region had an agricultural future and today draw great pride from their achievements. Granted they would never have been able to do this without state support, not all regions that received state support were able to succeed economically as well. In the following chapters I explore the implications of such a story on the land clearing history and the environmental vision and values of these producers.

Chapter 3. Environmental policies addressing land clearing in the Amazon-Cerrado transition area of the Legal Amazon

1. THE EXPLOSION OF AGRICULTURAL PRODUCTION IN THE AMAZON-CERRADO TRANSITION AREA OF MATO GROSSO

According to the estimates provided by the PRODES,[106] deforestation up to 2014 represented around 750,000 square kilometers (km^2), 18% of the original 4.1 million ha occupied by forests in the Legal Amazon (Le Tourneau 2016).[107] In just three decades, between 1988 and 2017, an area slightly larger than Paraguay and smaller than Sweden was converted to human activities (i.e. 420,000 km^2), with average deforestation rates as high as 19,625 km^2 per year over the 1996-2005 period (INPE 2018a). Meanwhile, the Cerrado biome had lost approximately 46% of its original cover by 2017 (i.e. 880,000 km^2) (Strassburg et al. 2017; Carneiro and Costa 2016).[108] What is more, the deforestation in the Cerrado biome has often been more acute than in the Legal Amazon,[109] as Strassburg et al. demonstrate that: "Between 2002 and 2011, deforestation rates in the Cerrado (1% per year) were 2.5 times higher than in the [Legal] Amazon" (Strassburg et al. 2017: 1). Despite a recent and spectacular reduction in deforestation rates over ten years (2004-

[106] Program for the monitoring of Brazilian Amazon Forests by Satellite. In Portuguese: "Monitoramento da Floresta Amazônica Brasileira por Satélite."

[107] The number of 750,000 km^2 is superior to the 450,000 km^2 appearing on **Figure n°3.1** because the latter does not take into account deforestation prior to 1988. Deforestation estimates by the INPE before that date lack accuracy, and only go back as far as 1975. Some authors thus estimate deforestation for the 1978-1988 period to be 20,400km^2 per year on average, and they recommended to add 100,000 km^2 of deforestation for the period prior to 1970 (Fearnside 2003). I did not include the deforestation for the Cerrado biome on this figure because the official data allowing to segregate land clearing across biomes is not available before 2000 (i.e. Individual deforestation polygons are available only starting in 1997 for the Legal Amazon, and 2000 for the Cerrado biome).

[108] It has originally lost even more original cover, but the biome recovered partly from human disturbances (Jepson 2005)

[109] As a reminder, the PRODES deforestation data captures all deforestation of forests happening in the Legal Amazon. It imperfectly captures land clearing in the Cerrado biome portion of the Legal Amazon although it might sporadically spot deforestation events there. The official estimates of deforestation for the Legal Amazon (mostly Amazon biome) and the Cerrado biome thus have to be read with caution, since there may be some double counting in the data, since the Cerrado biome data includes the Cerrado portion of the Legal Amazon (also counted, very inaccurately, by the PRODES).

2014) following governmental efforts to curb deforestation (focused mostly on the Legal Amazon), the phenomenon persists as deforestation has increased since it reached its lowest point of 4,600 km^2 in the Legal Amazon and remained stable around 9,545 km^2 in the Cerrado in 2012.[110] Since then, deforestation rates averaged 6,600 km^2 per year in the Legal Amazon and about 9,300 km^2 per year in the Cerrado biome casting serious doubts on whether public policy and market initiatives for forest conservation will succeed in eliminating deforestation (**See Figure 3.1**) (Trase 2018).

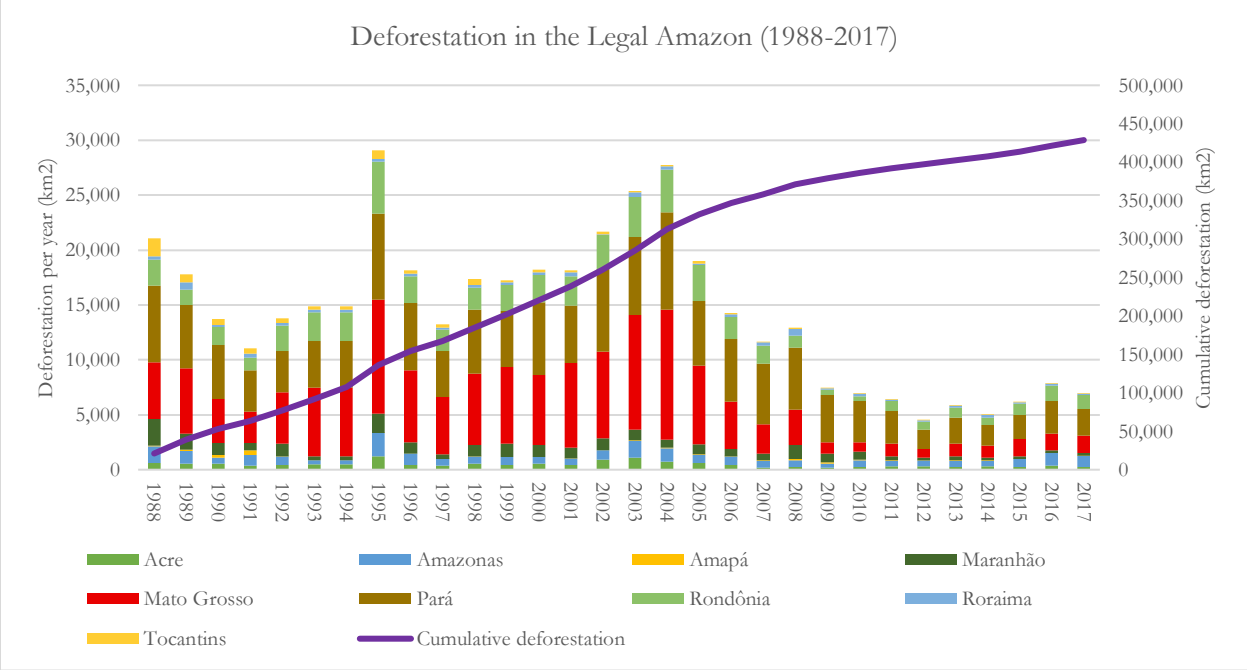


Figure 3.1. Official deforestation in the Legal Amazon region between 1988 and 2017 as estimated by the PRODES (INPE, 2019). **Note**: the cumulative deforestation curve on this graph does not take into account deforestation prior to 1988, therefore it only indicates 450,000 km2 of cumulative deforestation instead of the 750,000 km2 estimated loss over the entire history of land-use of the Legal Amazon.

The persistence of the issue demonstrates that both uniform policy approaches at the regional level (i.e. the Legal Amazon) and specific approaches at the state- (e.g. Mato Grosso, Pará) or

[110] Deforestation rates decreased more in the Amazon biome than in the Cerrado, although both biomes experienced similar spectacular drops in land clearing rates. Deforestation in the Legal Amazon passed from 27,772 km2 in 2004 to 4,571 km2 in 2012. In the Cerrado biome, land clearing rates dropped from 29,962 km^2 in 2004 to 9,545 km^2 in 2012 (INPE 2018b, 2018a).

sectoral-level (e.g. moratorium on soybean or beef production) have all had their limits despite achieving substantial reduction in deforestation rates. Authors have criticized the idea of Amazon deforestation as one uniform and giant "deforestation arc", pointing to the specificity of each local situation and saying that federal policies do not take into account the fine-grained differences in socio-economic drivers from one locale to the other (Becker 2010). They emphasized that a uniform approach to deforestation is misguided since there are multiple frontiers subject to different forces, explaining why deforestation stopped in some places but persisted in others (Brondizio and Moran 2012; Le Tourneau 2016). However, few studies have tried to explain why deforestation stopped in some places but not in others following the reinforcement of environmental policies since the 2000s. Hence, it is particularly relevant to examine the underlying reasons land clearing has receded in "consolidated" frontiers such as the BR-163 and the Chapada dos Parecis.

Focusing on the study area, the objective of Chapter 3 is to replace environmental policies in the context of Mato Grosso and assess to what extent the mechanisms of these policies have applied to the study area.[111] A central tenet of this chapter is to demonstrate that the reinforcement of the monitoring and enforcement of environmental policies in the 2000s only limitedly affected the study area. Most of the BR-163 highway area and Chapada dos Parecis included analyzed in this dissertation is located in the Cerrado biome, at the exception of Sinop and the northern part of Sorriso. The PRODES and DETER[112] programs only monitor deforestation in the Amazon biome, and therefore most of the governmental pressure to stop deforestation occurred in that biome. As

[111] Chapter 4 will provide an in-depth analysis of landowners' responses to policies at the property-level.

[112] Deforestation Monitoring System for the Legal Amazon ("Sistema de Monitoramento do Desmatamento na Amazônia Legal" in Portuguese)

a result of these conditions, the Amazon-Cerrado transition area, in which most of the producers interviewed are located, has escaped much of the federal pressure against deforestation (while not remaining unaffected by it either directly or indirectly) and important areas of forests in the Cerrado (the transition areas) were cleared. Thus, the particular geographical focus of this dissertation, examining rural properties located in a gradient of vegetation types and biomes, makes it a compelling case for studying how landowners responded differently to policies in an area not receiving intense environmental policy enforcement pressure.

"Deforestation" and "land clearing" are expressions that will be used alternatively in this chapter. The native vegetation cover protected within private rural properties under the Brazilian Forest Code (FC) can be forests or some other type of vegetation cover, depending on the region considered (e.g. savannahs, grasslands, woodland, etc.). Since this study focuses on the Amazon-Cerrado transition areas, many properties originally had both types of land cover within their boundaries. Although it would be more appropriate to only use "land clearing" to describe the phenomenon of interest, most policies regulating the clear cutting of native vegetation are commonly referred to as "deforestation policies" because they most often serve to prevent the clearing of forests. However, non-forest vegetation types are also subject to such policies. To avoid overly complicated distinctions for discussing policies, I use both "deforestation" and "land clearing" alternatively to describe *the clear cutting and replacement of the original vegetation with fields or pasture*, unless otherwise stated. Chapter 4 will provide a careful discussion of the exact proportion of forests and other types of vegetation that soybean producers cleared.

The remained of this chapter is divided into 3 sections after this Introduction. First, I review the literature about the role of individual actors in tropical deforestation. This section details why it is necessary to study the decision-making of local actors to understand the mechanisms by which environmental policies may mediate these decisions. Section 3 provides an extensive review of the history of Brazilian anti-deforestation policies, the complexity of which only illustrates how much of a "black box" they represent in tropical deforestation models. Section 4 concludes the chapter with a review of the effectiveness of such policies and discusses their limited relevance for the Amazon-Cerrado transition areas (the study area), especially since most assessments have focused exclusively on the Amazon biome.

2. A BRIEF OVERVIEW OF THE DEFORESTATION DRIVERS IN THE BRAZILIAN AMAZON

2.1. THE ROLE OF INFRASTRUCTURES AND IMMIGRATION

Infrastructure expansion has long been the focused of scholars studying Amazon deforestation, and rightly so as the beginning of the phenomenon is marked by the construction of federal highways slicing the region in multiple parts and connecting migration routes from Northeast and Southern Brazil to the Amazon. Perhaps road impact is best exemplified by the temporary "fishbone" deforestation patterns one can observe from satellite images, which is the result from both loggers and colonist settlements or agrarian reform projects (Arima et al. 2005). Some roads are the result of large federal infrastructure projects while others are unofficial or illegal projects initiated by various actors (e.g. loggers, speculators, etc.). A recent study taking into account the existence of both types of roads, as well as waterways, concluded that the overwhelming majority of deforestation (94.9%) occurred within 5.5 km of all types of roads or 1km of a navigable river

(Barber et al. 2014). Yet, correlation does not mean causation and roads north of the Amazon river have proven to be surrounded by less deforestation than their counterpart in on the southern side (e.g. the road from Manaus to Porto Velho) (Le Tourneau 2016). It is thus uncertain whether new roads may bring the same amount of deforestation in the future since this effect is mediated by other ones (e.g. presence of conservation units, state presence, etc.).

Population migration has historically been an important factor in deforestation but the pattern of its influence has been changing. Between 2000 and 2010, around 1.8 million persons migrated to Legal Amazon states, against 1.5 million between 1990 and 2000 (IBGE 2018). However, these migrants came increasingly from the Amazon itself, pursuing a shift from long distance, inter-regional migration (e.g. from the South of Brazil to the Amazon) to intra-regional migration (within Amazon states) which started gradually in the 1980s (Campari 2005). Today, the relationship is however far more ambiguous and not linear. Analyzing deforestation and census tract population data between 2000 and 2010, Tritsch and Le Tourneau (2016) found in many instances that high population density co-existed with preserved forests, and that, on the contrary, 1.5% of the Amazon population was associated with one third of the area deforested. This demonstrates that the relationship between population and deforestation is weaker than in the past and invites researchers to study this element not separately but following its interactions with other factors. Finally, it is important to underline that rural-urban migration has been increasing and today 69% of the Amazon population lives in cities (Brondizio et al. 2016).

2.2. THE HISTORICAL ROLE OF CATTLE-RANCHING

Although almost inexistent in the 1970s, cattle-ranching has historically been the single-most important cause of deforestation in the region, with 85% deforested areas occupied by pastures (Bowman et al. 2012; Barona et al. 2010). From the 1960s to the 1990s, cattle-ranching was strongly supported by subsidized credit and tax incentives encouraging ranchers to occupy and claim land property rights in the Amazon region. Cattle-ranching fulfilled three important roles for colonizers. First, it served as a reserve value of capital in areas where market access was poor due to a lack of infrastructures because cattle-ranching provided a financial security that crops did not since it is not season-dependent. Cattle can be sold at different times during the year while rice only at the time of harvest more or less common to all farmers, hence the price drops at that time. Furthermore, when the price fluctuates, farmers in poorly connected areas have no choice but to be price-takers while ranchers can always wait for the price to bounce back up. Second, it helped colonizers to claim property rights over large land areas since the herd can be moved around easily. Consequently, ranching helps capturing land value while also providing a hedge against inflation. Third, the fact that cattle-ranching projects were the recipients of many fiscal incentives in the early days of Amazon colonization (Hecht 1985b; Philip M. Fearnside 2005b) attracted speculators who knew that this activity potentially entailed low maintenance costs. Part of the cattle-ranching expansion has thus been an artifact of tax policies of the 70's and the 80's.

The 1990s has seen a switch in the factors of cattle expansion with the abandonment of many incentives in the late 1980s and the increase in domestic and global demand for beef. Among domestic/regional factors, the urbanization of Amazonia (e.g. Manaus) and rising of a middle-class, as well as the signing of the MERCOSUL, stimulated both domestic and regional trade.

Among global factors, the occurrence of Bovine Spongiform Encephalopathy (BSE) in Europe and the U.S. stimulated the demand for crop-based feed (i.e. soybean) as well as grass-fed beef in Brazil. According to Bowman, "beef exports grew from approximately 5% to 20% of production between 1990 and 2007" (Bowman et al. 2012: 559). This was accompanied by improvements in agricultural practices (i.e. sanitation, herd management) allowing to control the foot-and-mouth disease which was necessary to get clearance for exportation. Today, ranchers capture value through both the inflated land value due to tenure security resulting from stabilized ranching operations and the value of beef production itself. Because they can play on both fronts, pastures expand in places where cattle-ranching is only marginally profitable but where land speculation is likely, principally in areas that can be sold to soybean producers at a higher price in Mato Grosso or around Santarém in Pará (Bowman et al. 2012).

2.3. THE ROLE OF SMALL-SCALE AND LARGE-SCALE FARMING: THE INCREASING ROLE OF SOYBEAN AS AN INDIRECT CAUSE OF FOREST CONVERSION

As explained in the very introduction of this dissertation, whether deforestation is the fact of small or large farmers has been subject to much debate in the Amazon, and understandably so as identifying such thing would put the blame on either of these groups and determine what tools must be adopted to fight against deforestation (Philip M. Fearnside 2005b). If it is generally recognized that small-scale landowners tended to deforest a larger share of their property (as it is necessary to have a profitable farm in the Amazon when it is below 50 or 100 hectares and as exemplified by agrarian reform settlements), large-scale landowners tended to deforest a smaller portion of their property but contributed to the largest share of absolute deforestation (Le Tourneau 2016; Brondizio and Moran 2012; Brondízio et al. 2013). It is important to note that the

contribution of large landowners in the total share of deforestation has however greatly decreased (by 63% between 2004 and 2011) since the federal government enacted strong anti-deforestation policies in 2004 (Godar et al. 2014a).

Contrary to the popular image according to which most deforestation was due to pasture expansion, the historical role of soybeans and large-scale agriculture has increasingly been pointed out (Philip M. Fearnside 2001). Agricultural expansion linked to soybean was initially present in the Cerrado biome areas located southeast of the Legal Amazon, in Goiás, Mato Grosso do Sul, and around Rondonópolis, in Mato Grosso. Soybean rapidly expanded northward along the BR-163 (and is now even present in Santarém, Pará), the BR-364 in Rondônia, and more recently (in the 2000s) in the MATOPIBA region (comprising four states: Maranhão, Tocantins, Piauí, and Bahia) which includes a small but significant portion of the Legal Amazon (Trase 2018).

In the early 2000s, soaring soybean prices drew fears of massive deforestation caused by soybean expansion. Although some studies did not always find clear evidence for direct expansion of soybean over cleared forests between 2000 and 2006 (Barona et al. 2010), others found soybean represented 23% of direct deforestation in 2003 (Morton, DeFries, Shimabukuro, Anderson, Arai, del Bon Espirito-Santo, et al. 2006), and that "nearly 30% of soy expansion occurred through deforestation rather than by replacement of pasture or previously cleared lands" over the 2004-2006 period (Gibbs et al. 2015). Furthermore, Morton et al. (2006) demonstrate that clearings for soybean were on average twice as large as those for pastures, suggesting that large-scale landowners were responsible for this type of expansion.

Recent studies shed more light on the real extent of direct deforestation: "Between 2005 and 2016, at least 1.1Mha (an area larger than seven times the size of London) of native vegetation in the Amazon and Cerrado biomes were directly cleared for soy. This is 3% of the total area that soy now covers across Brazil, and 1% and 7% of the total area of soy in the Amazon and Cerrado biomes, respectively" (Trase, 2018: 40). Mato Grosso and Goiás drove much of that expansion with an agricultural area expanding from 7.5 m ha to 17.1 m ha between 2000 and 2017. Over 50% of that expansion occurred over former pastures, 20-30% occurred over native vegetation, and the remainder replaced other types of agricultural uses (i.e. other crops). Some areas have recently been more prone to direct deforestation, however, and this is especially the case of MATOPIBA in which 65% of all expansion between 2000 and 2017 took place over native vegetation (Carneiro and Costa 2016).

Recent progress in remote sensing has allowed some authors and professional organizations of soybean exporters to assess that the trend has decreased in the Amazon biome since various policy and supply chain interventions were made. Soybean cultivation only occupies about 1.2% of the Amazon biome and, in the 89 municipalities representing 97% of soybean cultivated in the Amazon during the 2016-2017 harvest, the crop is only responsible for 5.6% of direct land-use conversion from forests since 2008 (Rudorff, Adami, Aguiar, Moreira, Mello, Fabiani, Amaral, and Pires 2011; ABIOVE 2018). Nonetheless, the question is whether soybean expansion on Cerrado areas and former pastures push other land-uses father away into the Amazon forest. Calling this approach indirect land-use change (ILUC), authors have argued that soybean expansion tends to contribute to deforestation indirectly by displacing cattle-ranching further deep into the Amazon (Arima et al. 2011). According to Richards et al. (2014) a third of the

deforestation occurring between 2002 and 2011 would be indirect result of soybean expansion elsewhere. The authors note however that this effect has significantly declined since 2006 revealing how this pattern may be changing.

Given that cattle-ranching was historically responsible for the bulk of clearing in the Amazon rainforest, it is important to bear in mind that environmental policies were designed to address this issue. Most soybean expansion occurred in the Cerrado, a biome that did not receive as much attention from policy-makers.

3. THE BRAZILIAN ENVIRONMENTAL POLICY RESPONSE TO DEFORESTATION

Most studies about tropical deforestation only take into account a restricted set of public policies that generally exclude environmental policies: taxation, agricultural credit or subsidies, economic development program, land tenure, and so forth (Geist and Lambin 2001). The particular case of Brazilian Amazon deforestation calls however for a greater consideration of anti-deforestation policies. In this section, I will review the evolution of environmental policies in Brazil and Mato Grosso while the next section is dedicated to the existing evidence about their effectiveness.

3.1. The evolution of Brazilian environmental policy: the central role of the Forest Code

3.1.1. The protection of Brazilian native vegetation under the 1934 and 1965 forest codes (1934-1987)

The Forest Code (FC) is the central piece of Brazilian's land-use policies and perhaps one of the most ambitious and innovative environmental legislations in the world. It was one of many key legislations (alongside changes in labor, education, health policies) passed during the intense reform period under the dictatorship of the *Estado Novo* of Getúlio Vargas. Since its creation in 1934,[113] it requires all landowners to preserve riparian forests for the variety of health and ecosystem services they provide, forests being seen in this legislation as common goods concerning all inhabitants of Brazil.[114] Going against the idea of an absolute dominion of private owners over their land, it created the *quarter rule*[115] which required private owners to conserve 25% of the *existing*[116] forests present on their property. This rule applied to the property as a whole, and thus aimed to preserve not only riparian forests but forest patch in the property. It also meant that up to 75% of the forests remaining on a property at the time of the FC could be subject to clearing. Along with this rule, the clearing of *protective forests*[117] located around riparian areas and water bodies was forbidden, as their function was defined as protecting waters, limiting soil erosion, fix dunes, and others ecosystem services. The Forest Code also created conditions and procedures for land clearing, most notably prohibiting the use of fire without prior authorization

[113] Decree n°23.793 of January 23, 1934

[114] Art. 1, Decree n°23.793 of January 23, 1934

[115] Art. 23, Decree n°23.793 of January, 23 1934. "Quarta parte" in Portuguese. The text of Art. 23 states the following: "no owner of forested land can clear more than three quarters of the existing vegetation, save the dispositive in articles 24, 31, and 52." The original text is: "Nenhum proprietario de terras cobertas de mattas poderá abater mais de tres quartas partes da vegetação existente, salvo o disposto nos arts. 24, 31 e 52"

[116] Daugeard (unpublished) notes that the ambiguity of this rule concerning only *existing* forests on the property will lead to some serious rule interpretation disagreements and enforcement problems.

[117] In Portuguese, "florestas protetoras"

for such purpose. Very innovative for their time, these rules did not exclusively have symbolic value since the decree also contained the creation of a "forest police" in charge of monitoring and applying specific fines for all forest-related crimes (Daugeard unpublished).

Despite the innovativeness of these rules, the FC lacked clarity and was difficult to enforce (i.e. weak capacity of enforcement bodies). It was substantially reformulated in 1965 with a second Forest Code[118] after long debates spanning back to the 1950s (hereafter "1965 FC"). This law reinforced the idea of a required preserved area on each property (i.e. *quarter rule* of 25%) by imposing higher conservation percentages based on the *location* of the property in Brazil. The percentage of native vegetation to be preserved jumped up to 50% in the Northern and Center-West[119] regions while it was set at 20% for previously cleared properties in the South. New properties in the South that had not been partially cleared were subject to a 50% limit (Azevedo 2009). The boundaries for new conservation percentages were strikingly unclear. The dividing line between areas with different percentages of preservation was "drawn" mostly within the Center-West region.[120] It split the Center-West into an arbitrary "northern" section where the 50% limit applied, and a "southern" part with the 20% limit

Very importantly, these percentages no longer applied to just the *existing* share of vegetation present, but to the total property area.[121] The second Forest Code of 1965 also reinforced the

[118] Law n°4.471 of September 15, 1965

[119] Only in the northern part of the Center-West region

[120] Reminder: comprising the states of Goiás and the to-be-divided state of Mato Grosso (divided in 1977 into Mato Grosso do Sul and Mato Grosso). Part of this area is contained within the Legal Amazon while the Goiás and Mato Grosso do Sul part, is outside these boundaries)

[121] The detail of this rule change can be explained with the example of a 1,000 ha property in the South with 500 hectares of existing forest cover. According to the first Forest Code of 1934, 25% of the *existing* vegetation (500 ha) here must be preserved, so 125 ha. According to the second Forest Code of 1965, since this property is located in the South and already partly cleared, the owner has to preserve 20% of the entire property (1,000ha). As a result, the

preservation of "protective forests" by creating a larger category of "zones of permanent protection"[122] to designate riparian and hilltops forest areas which cannot be cleared under any circumstances. The extent of such areas varied and were proportionate to the size of the water bodies they protected (e.g. a river with a 10-meter width had to have 1 to 5 meters of forest buffer while 200-meter wide rivers required 100-meter forest buffers). Although this second FC contained the seeds for two of the most important notions of Brazilian environmental law, namely the Legal Reserve (LR) and Areas of Permanent Protection (APP), history repeated itself in the sense that federal agencies in charge of enforcing the law were never properly capacitated which left landowners unmonitored.

3.1.2. The *Nossa Natureza* program and heightened scrutiny over Amazon deforestation (1988-1995)

The launching of the "Our Nature" program ("Nossa Natureza" program in Portuguese) by President José Sarney on October 12, 1988, inaugurated an era of heightened concern over the fate of the Amazon forest for the Brazilian government. The PRODES was created to monitor deforestation by satellite and new laws were passed to increase forest protection in the Legal Amazon, with ambivalent effects for biomes other than the Amazon. In 1989, a reform of the FC[123] increased the share of areas under permanent protection by creating a 50-meter forest buffer around water springs. It turned forest reserves located on private properties into an official category named Legal Reserve (LR). Specifically, to accommodate the expansion of agriculture in the Cerrado, it set the LR to 20% in Cerrado areas across the country (but it remained silent about forests in

landowner will have to preserve not 125 ha but 200 ha operating an effective conservation obligation change of 12.5% to 20%.

[122] Art. 2, of Law n°4.471 of 1965

[123] Law n°7.803 of July 18, 1989

transition areas) (VanWey et al. 2013). It is of utmost importance to highlight that, at the time, the legislation referred to 'Cerrado' and 'Amazon' as vegetation types but not as the boundaries of biomes as understood today.[124] The "changing" notion of what these vegetation types are and their boundaries would create room for confusion in law implementation across Brazil and especially in Mato Grosso where one vegetation type gradually transitions into the other (Chaib Filho, Garagorry, and Machado Júnior 2002). The boundaries of the Cerrado, Amazon, and other biomes only started emerging in 1988 based on maps of the Brazilian Institute of Geography and Statistics (IBGE) (Rajão, Carvalho, and Giucide 2018).Their final versions were not validated until 2004 with the Brazilian Biome maps created by a joint partnership between IBGE and the Environment Ministry (MMA).

This meant in practice that areas located both in the northern part of the Center-West region (criterion of the 1965 FC) and in the Cerrado (new criterion of the 1989 law) saw the area they needed to preserve pass from 50% to 20%. This made forests located in predominantly-Cerrado areas more vulnerable since their preservation depended on environmental bodies' interpretation of whether to classify them as "forests" or "Cerrado." Happening when agricultural expansion was taking off in the Amazon-Cerrado transition areas of Mato Grosso, this law change demonstrated the ambivalent effect of policies prioritizing the protection of the Amazon biome that ended up weakening the protection of Cerrado's native vegetation.

In 1989, *the government* made another step toward enforcing the FC by obligating landowners to declare the 20% LR onto their land titles (Santiago et al. 2017). The goal of this registration

[124] Note that the 2012 Forest Code does not refer to biomes for the calculation of LR, only for the compensation of LR.

(called "*averbação*") was to prevent successive landowners with different land-use priorities from clearing this area. Properties transferred from one landowner to another were especially subject to a fragmentation of the LR. Previously, under the 1934 FC, the law only stated that landowners with forested land could not clear more than three quarters of their area. This formulation created a loophole by which landowners could divide their property in two, one property containing the 75% of cleared area and another one containing the 25% of preserved forests. Three quarters of this "new" forested property could in turn be cleared by the same landowner or, if the property was sold to someone else, by another landowner (Castro 2013). Given the important deficit of LR observed in some regions, the Agricultural Policy law of 1991[125] further demanded that all landowners register this LR percentage within 30 days.

3.1.3. The Provisional Measure of 1996: a hollow response to deforestation peaks (1996-2003)

In 1995, deforestation rates in the Amazon reached a record peak of 29,100 $km^2$of cleared area, prompting a panic response from the government of President Fernando Henrique Cardoso which led to the issuance of a provisional measure[126] to address the situation. The key Provisional Measure n°1.511 of 1996[127] limited clearing to 20% of properties located within the Legal Amazon with forest characteristics.[128] First, it applied this new limit (i.e. a LR of 80%) to the Northern and Center-West region of Brazil, above the 13th Southern parallel, roughly comprising the Legal Amazon but missing the southern three quarters of Mato Grosso, which (legally-speaking) fully

[125] Law n°8.171 of January 17, 1991
[126] A Provisional Measure (or *Medida Provisoria* in Portuguese) is a law directly issued by the executive branch of the government and which does not necessitate the Parliament approval to enter into force.
[127] Provisional Measure n°1.511 of July 25, 1996
[128] Note: the "Legal Amazon" term is not used in the law

belong to the Legal Amazon.[129] Second, this provision increased the 50% LR of the 1965 FC to 80% in any areas of *forest type*.[130] By playing on these two criteria, it increased the confusion around the preservation of native vegetation especially in Mato Grosso[131]. The fact that Mato Grosso was located in the Center-West region and presented a gradient of forest cover distribution across its three biomes (Amazon, Cerrado, and Pantanal) contributed to create a very confusing environment for law interpretation and implementation.

The Provisional Measure of 1996 was created to address the critical situation for the Amazon forests and appease fears of environmentally-concerned actors both in and outside the country (e.g. environmental NGOs, development funding countries, general public) who expressed concern over deforestation rates. However, as a result, many landowners in the Amazon region found themselves turned into criminals over night because they did not have enough forests set aside to comply with the new LR percentages. Increasing the pressure, the federal government passed a regulation[132] in 1999 creating the legal framework for imposing criminal sanctions to landowners clearing LR vegetation.

The Provisional Measure also triggered a 15-year legislative movement of legal instability that culminated with the revision of the FC in 2012 (Daugeard unpublished). The agricultural sector,

[129] The Provisional Measure of 1996 delineates the Northern and Center-West region as comprising the states of Acre, Pará, Amazonas, Roraima, Rondônia, Amapá and Mato Grosso, and all the area above the 13° southern parallel in Tocantins, and the area situated west of the 44° Western longitude in Maranhão (Art 1, §3, Provisional Measure n°1.511 of 1996). It therefore excludes part of the Legal Amazon as defined by the Complementary Law n°31 of October 11, 1977 which contains the entire state of Mato Grosso since the division of Mato Grosso into 2 states (i.e. Mato Grosso do Sul being the other state) (See Art. 45 of this law). Note: It is thus in 1977 that the criteria set up by the law of SPVEA

[130] In Portuguese, "areas de fitofisonomia floresta"

[131] See the discussion on transition areas in the review of Mato Grosso's environmental policies

[132] Decree n°3.179 of September 21, 1999

landowners, and corporations, represented by a group known as "*bancada ruralista*"[133] at Congress, worked to undermine the Provisional Measure. Indeed, the measure did not persist long before the 17th revised version replaced it in June 1997. In total, over the course of the next 5 years (between 1996 and 2001) this provisional measure was re-issued 67 times, which can be explained partly by the fact that provisional measures are valid for 70 days and can be renewed for an equal period of time after expiring (Santiago et al. 2017). Although a majority of revisions did not change the substance of the regulation, some gradually introduced changes and new concepts. For example, a 1998 measure[134] introduced the possibility for landowners to compensate for their LR deficit by purchasing new areas covered with forests. Compensation is only possible if the area fulfills the following conditions: 1) it is located within the Legal Amazon; 2) it belongs to the same biome; 3) it is located within the same state. A second measure in 1998[135] lowered the percentage of LR for Cerrado areas located in the Legal Amazon to 20%, potentially removing the 50% protection of forested areas located in Cerrado areas established by the temporary measure of 1996.[136] This change, one of 67, was too short-lived to represent a significant change in environmental policy enforcement.

Hoping to clarify the situation once and for all, a new provisional measure was adopted in 2001[137] to clearly define the meaning and scope of both the APP and the LR. In fact, this one was the last

[133] This nickname usually designate a more formal group called "Frente Parlamentar da Agroepecuária".
[134] Provisional Measure n°1.605-30 of November 19, 1998
[135] Provisional Measure n°1.736-31 of December 14, 1998.
[136] Article 44 of Provisional Measure n°1.736-31 of December 14, 1998, stated that if the "forested cover" is 50% then clearing is allowed, and the limit should go down to 20% in areas covered by Cerrado. What each of these categories represent was left to interpretation by environmental bodies and local actors. Original text of Art. 44: "Na região Norte e na parte norte da região Centro-Oeste, a exploração a corte raso só é permissível desde que permaneça com cobertura arbórea pelo menos cinqüenta por cento da área de cada propriedade, limite que será reduzido para vinte por cento, quando se tratar de área coberta por Cerrado."
[137] Provisional Measure n°2166-67 of August 26, 2001

of a long series of measures and it repeated the content of a temporary measure from 2000.[138] The 2001 measure not only confirmed the 80% LR of properties located in forested areas, but also finally increased the LR for Cerrado areas from 20% to 35%, while preserving the 20% LR for the rest of the country. The measure turned the areas of permanent protection into an official category bearing a similar name ("Areas of Permanent Preservation" which has the same acronym: APP). To ease compliance, it allowed for the incorporation of APP areas into the LR percentage under certain circumstances. It also created different avenues for rural property compliance inviting landowners to either (1) Reforest their properties with native species; (2) Allow the LR to regenerate naturally, or; (3) Compensate the LR deficit with the purchase of an area covered in native vegetation in an official Conservation Unit or a private property located in a similar ecosystem or river-basin. This marked the end of an era of particular legal instability (i.e. through the use of temporary measures) at the federal-level, but did not mean the end of the legal instability at the state-level in Mato Grosso.

3.1.4. The strong federal response to the return of high deforestation rates (2004-2011)

This period of legal stability regarding the rules of the Forest Code was however, marked by instability in deforestation rates. In the 2002-2004 period, the combination of high commodity prices, increased cattle-ranching, weak forest policy enforcement, and announcements about the creation of large infrastructures in the Amazon probably caused another high deforestation peak of 27,800 km^2 (Pires 2014). This prompted a new "panic" response from the government (of Luiz Inácio da Lula Silva this time). Convinced of the necessity of an inter-ministerial cooperation to

[138] Provisional Measure n°1.956-50 of May 28, 2000

tackle deforestation by the environmental minister at the time (Marina Silva), the government created the Action Plan for the Prevention and Control of Deforestation in the Legal Amazon (Plano de Ação para Prevenção e Controle do Desmatamento na Amazônia Legal - PPCDAm) in April 2004 with 4 goals in mind for its first phase (2004-2007): (1) territorial planning and land tenure regularization; (2) environmental monitoring and enforcement; (3) support to sustainable production activities; (4) creation of sustainable infrastructure. As explained by Pires (Pires 2014), the assassination of Sister Dorothy[139] in 2005 sent an additional shockwave that legitimized the government's intention to make the PPCDAm its main policy for the region. The PPCDAm created a new regulatory framework for national forests that established 25 million hectares of Conservation Units (e.g. Estação Ecológica Terra do Meio and the Parque Nacional Serra do Pardo, both located in Pará) and the legalization of 10 million hectares of Indigenous Territories throughout the Amazon. The idea was to create a "green wall" (Freire 2014: 221) impeding agricultural expansion around the main Amazon highways such as the BR-163 highway. Though not all areas were officially created, Brazil was nonetheless responsible for the creation of 74% of all new protected areas in the world between 2004 and 2009 (Jenkins and Joppa 2009).

The PPCDAm included an enforcement aspect ordering the Brazilian Institute for the Environment (Instituto Brasileiro do Meio Ambiente – IBAMA), the federal environmental agency in charge of environmental policy enforcement, to crack down on illegal deforestation (especially illegal logging activities), which it did through several spectacular operations widely covered by the media. In 2005, the *Curupira* operation of the Federal Police jailed numerous civil servants from the state environmental body (FEMA) and from the Superintendence of IBAMA in Mato

[139] Sister Dorothy Stang was an American-born high-profile Brazilian environmental activist working for the Pastoral Land Commission in Brazil. She was murdered in Anapu, Pará in 2005.

Grosso who were accomplices to a widespread corruption scheme involving illegal sawmills. In addition, deforestation monitoring was made stronger in 2004 when the National Institute for Space Research (INPE) created the DETER, a satellite-monitoring system in real time that could provide the rapid detection of clearing by 16-day period covering the Amazon biome (Assunção and Rocha 2014).[140] Although limited in resolution and capability (it could not detect deforestation through cloud cover) it considerably contributed to a timely enforcement of anti-deforestation actions, allowing the teams of IBAMA to be better equipped to react promptly and have some chance of catching the responsible agents before they completely deforested the area.

In spite of some good results, the return of deforestation in 2007[141] marked a second wave of anti-deforestation policies in 2007-2008. First, at the end of 2007, the government authorized by decree[142] the Environment Ministry (MMA) to create a deforestation "blacklist" containing the municipalities that deforested the most in the Legal Amazon. Called the List of Priority Municipalities,[143] it included municipalities based on the total area deforested, the area deforested within the last three years, and whether municipalities had experienced increasing deforestation at least 3 years out of the last 5 years. In February 2008, the MMA issued a list containing 36 municipalities[144] responsible for 50% of the total deforestation at the time and coordinated this

[140] The monitoring system only imperfectly captured forests in the Cerrado biome because of the diversity of vegetation types there. Hence, deforestation estimates in the Cerrado biome generated by this system are non-reliable.

[141] According to Pires (2014) this return was influenced partly by strikes in the enforcement teams of IBAMA following the separation of part of this federal body into the ICMBio (Chico Mendes Institute for Biodiversity Conservation) by the law n°11.516 of August 28, 2007, which is part of the National System for the Environment (Sistema Nacional do Meio Ambiente – SISNAMA). The ICMBio is in charge of managing and enforcing environmental law in Conservation Units.

[142] Decree n°6,321 of December 21, 2007

[143] "Lista dos Municipios Prioritários" in Portuguese, created by the Decree n°6.231 of December 21, 2007 and bearing the following name: "(Dispõe) sobre ações relativas à prevenção, monitoramento e controle de desmatamento no Bioma Amazônia, bem como altera e acresce dispositivos ao Decreto no 3.179, de 21 de setembro de 1999, que dispõe sobre a especificação das sanções aplicáveis às condutas e atividades lesivas ao meio ambiente, e dá outras providências"

[144] None of the municipalities of this study were included in the list, but several of their neighboring cities were.

announcement with an enforcement operation by IBAMA, named "Arc of fire,"[145] in all 36 municipalities of the list. These municipalities saw stringent reductions in the amount of agricultural credit available to them and were asked to proceed to several governance changes.

Second, the Brazilian Central Bank adopted a resolution[146] in 2008 restricting the allocation of rural credit to properties complying with environmental rules and demonstrating legal tenure for the entire Legal Amazon. In other words, its role was to cut access to credit for any rural property which did not have the minimum LR required by the law. As Chapter 2 demonstrated, public and private rural credit play an extremely important role in the funding of harvests, and even more so in the funding of equipment for soybean farmers (harvesting machines, etc.). Finally, the same year, the federal government reinforced sanctions against criminal infringements of the APP or LR areas by a decree[147] building on the 1999 law about environmental crimes. It expanded the principle according to which any property fined for illegal deforestation will also be put under an embargo status impeding landowners to sell the production originating from illegally-deforested areas on their properties. Landowners with an embargo were also prevented from accessing credit. Most importantly and controversially, the decree planned to sanction landowners who would have not declared their LR by a certain date with fines ranging from R$50 to R$500 per hectare and per day. The date of enforcement of this highly disputed provision would be regularly pushed back by legislative actions driven by the ruralist lobby until the eventual reformulation of the FC in 2012, virtually exempting landowners of this type of sanction (Daugeard unpublished).

[145] "Arco de Fogo" in Portuguese
[146] Central Bank (BACEN) Resolution n°3,545 of February 29, 2008
[147] Decree n°6,514 of July 22, 2008

Following these measures, deforestation rates throughout the Amazon region drastically declined although it remains fairly unclear whether they resulted from these policies or changes in global commodity prices occurring at the same time; some authors explain that both had a role (Assunção, Gandour, and Rocha 2015). Some of the successes were reinforced by the second phase of the PPCDAm (2008-2011) which was marked by the *Boi Pirata* operations that targeted illegal deforestation by cattle-ranching activities in Conservation Units. The Federal Prosecutor's Office ("Minsitério Público Federal" - MPF) of Pará started the *Carne Legal* operation which goal was to sue slaughterhouses and meatpackers sourcing cattle from illegally deforested properties. In the soybean supply chain, a group of multinational and national corporations exporting soybean to Europe signed onto the Soybean Moratorium, committing not to buy soybean grown on areas cleared after 2006 (later revised to 2008 to fit the Brazilian legislation).[148] The government also started the Action Plan for the Prevention and Control of Deforestation and Fires in the Cerrado Biome[149] (*Plano de Ação para a Prevenção e Controle do Desmatamento e das Queimadas no Bioma Cerrado* - PPCerrado) in 2010 to address the objectives of the national strategy to fight climate change. This strategy, formulated in a 2009 law,[150] set reducing Amazon and Cerrado deforestation as a priority for reducing greenhouse gas (GHG) emissions. At the time, Amazon deforestation represented about half (55%) of all GHG emissions in the country and was identified as the least costly way to reduce emissions (Freire 2014). Logically then, the Cerrado had to have its own land clearing monitoring system and the MMA created the Sattelite-Based Deforestation Monitoring Project in Brazilian Biomes (*Projeto do Monitoramento do Desmatamento nos Biomas*

[148] The major slaughterhouses controlling more than 50% of the Amazon's beef also signed onto a Zero Deforestation Cattle Agreement with Greenpeace. Both initiatives are discussed in further details later in this chapter.
[149] Decree n°12.867 of September 15, 2010
[150] National Policy on Climate Change (Política Nacional sobre Mudança do Clima - PNMC) – Law n°12.187 of December 29, 2009, regulated by decree n°7.390 of 2010.

Brasileiros por Satélite – PMDBBS) which documented that in 2002, already 889,172 km^2 (around 43.6%) of the Cerrado biome had been deforested.

3.1.5. The agricultural sector backlash and the "New" Forest Code of 2012

By 2008, the agricultural sector and the *bancada ruralista* had become so frustrated that the national debate about reformulating the FC was taken up, leading to its eventual reformulation four years later, in 2012. A first step was marked by the adoption of the *Mais Ambiente* program[151] which opened the possibility for landowners to get deforestation until 2008 "forgiven" by signing a document in which they laid out their plan to restore all illegally-cleared native vegetation. This plan imitated and extended the MT-Legal plan to the entire country (See next section for a description of the MT-Legal) (Rajão, Azevedo, and Stabile 2012). A Special Commission of the Forest Code (*Commissão Especial do Código Florestal*) of the Chamber of Deputies (*Câmara dos Deputados*) was formed in September 2009 to debate the different law proposals that were aimed to reform the FC. The new FC was finally adopted in May 2012[152] after a long conflict between ruralists and environmentalists, which would result in the veto of parts of the law by the president at the time, Dilma Rousseff.

The new FC tried to reach a balance between all interest groups and was considered by both camps (ruralists and environmentalists) as much a victory as a defeat. On the one hand, environmentalist obtained the maintaining of the 80% LR rule for the Amazon areas,[153] 35% for

[151] Decree n°7.029 of December 10, 2009
[152] Law n°12.651 of May 25, 2012
[153] For computing percentages of LR, the Art. 12, §1 of law n°12.651 of May 25, 2012 clearly refers to "areas" ("áreas" in Portuguese) of vegetation types of the Legal Amazon and *not to biomes*.

the Cerrado areas, and 20% for *campos gerais* of the Legal Amazon (Note: 20% for the rest of the country). On the other hand, ruralists benefitted from multiple adjustments in the rules which allowed them to be very frequently exempted of any concrete reforestation efforts, leading environmentalists to denounce this code as amounting to an "amnesty" for rural landowners. According to leading environmental NGOs such as Greenpeace, WWF, the Instituto Socioambiental (ISA) and the Instituto de Pesquisas da Amazônia (IPAM), the FC resulted in excusing illegal deforestation in 90% of all rural properties in Brazil (Freire 2014). *It is however not the objective of this section to judge who was the "winning side" of this reform*. The new FC opened up the way for rural properties' compliance by requiring landowners to follow an Environmental Regularization Plan (*Plano de Regularização Ambiental* – PRA), to be signed with the state regulator, and which allowed for the suspension of any fines (i.e. before 2008, see below) imposed upon the landowner for violation of any part of the law (i.e. regarding non-compliance with APPs, LRs, or any other aspects).

The 2012 FC however made the compliance of landowners more flexible. First, the provisional measures starting in 1996 had created some legal challenges to FC compliance since the new rules imposed increased LR percentages to all landowners regardless of whether some individuals had deforested beyond these limits prior to the law change. To account for this, the 2012 FC thus created a legal regime for already-deforested areas called "consolidated areas" and the date chosen for determining them was July 22, 2008.[154] Under the current law, landowners with consolidated

[154] In reference to the decree n°6.514 of 2008 requiring landowners to declare their LR. Daugeard (2018) notes that this decree only reinforced the law n°9.605 of 1998 and would have thus represented a more logical reference date since it had occurred right after the increases in LR and APP requirements of the Provisional Measure n°1.511 of 1996. Daugeard also indicates that this date choice may also have been influenced by the high amount of deforestation occurring between 1998 and 2008, which was equivalent to that between 1988 and 1998.

areas have to respect different limits for APPs than landowners who are clearing a new property (after July 22, 2008) in order to account for "anthropic uses" (i.e. buildings, installations and cattle-ranching uses) present prior to this date. Second, as a result of this reform, it is now necessary to analyze deforestation through satellite images in order to know if a landowner was infringing the LR percentage in effect *at the time* the clearing occurred. For example, in the case of a landowner in the Amazon who respected the 50% LR limit existing before the Provisional Measure of 1996,[155] the new FC does not make it necessary to reforest areas up to the new 80% limit. In Mato Grosso, landowners who deforested up to 50% of their property in forested areas and 20% in the Cerrado areas before May 26, 2000[156] are therefore considered to comply with the new FC. Farmers who had started to deforest before that date but who still hold more LR than the limit in effect at the time benefit from a special treatment with respect to LR restoration. For instance, a landowner in forest-dominated areas with a property area over 4 Fiscal Modules[157] (FMs) and who had 67% of his property under LR before May 26, 2000 will have to restore it up to 80% but does not need to engage into a PRA (Daugeard unpublished).

Third, the new FC exempted landowners with properties below 4 fiscal modules from reforesting the areas cleared in excess of the LR limit at the time of consolidation of the property (i.e. when the clearing was done). For them, the amount of LR existing on the property on July 22, 2008 became the (property-specific) LR percentage they had to comply with.[158] In the Amazon landowner example cited above, it means that 67% is the LR percentage to be respected provided

[155] Original limit change of 50% to 80% with the Provisional Measure n°1.511 of 1996 and original limit change of 20% to 35% of the Cerrado with the Provisional Measure n°2166-67 of August 26, 2001. Importantly, this date may vary by state, which is the case of Mato Grosso where the reference date is May 26, 2000.

[156] Date of the Provisional Measure n°2080-58/2000 which translated the Provisional Measure n°1,511 of 1996 in Mato Grosso.

[157] See Introduction to this dissertation for an explanation of Fiscal Modules

[158] Art. 67, Law n°12.651 of May 25, 2012

that the property is inferior to 4 FMs. This exemption was particularly pointed out as an "amnesty" by environmentalists since it "excused" any illegal deforestation in the LR well after the percentage had changed in 1996 (about 12 years after). Finally, it reduced the buffer or native vegetation necessary in riparian areas and allowed for the incorporation of the APP into the percentage of LR regardless of any conditions. One problem introduced by this provision is that landowners can divide their properties such that each of the smaller pieces fall under 4 fiscal modules. In the municipalities of the study, one fiscal module is either 90 ha (in Sorriso and Sinop) or 100 ha (in other municipalities). This means that a farmer with a 2,000 ha property can divide it into 5 or more properties of 400 ha or less, through family succession for instance, and avoid compliance with the FC.

A central innovation of the new code is that all rural landowners are now required to declare their APP and LR area in a Rural Environmental Cadaster (*Cadastro Ambiental Rural* – CAR) system. The idea of this system is to get landowners to register their property area into a geographic information system (GIS) database which would establish compliance by determining the excess or deficit (also called "environmental deficit"[159]) of APP and/or LR. Following a PRA which serves as "road map" toward regularization, landowners are offered different paths toward the regularization of a LR deficit: (1) natural regeneration; (2) forest restoration; (3) compensation. The last possibility can occur through a variety of actions. Landowners can compensate their LR deficit with an existing excess of LR in another property or a third party's property, provided that the areas to be compensated are located within the same biome. In the latter case, LR areas that are in excess of the minimum requirement can be transformed in Environmental Reserve Quotas

[159] "passivo ambiental" in Portuguese

(*Cota de Reserva Ambiental* – CRA) and traded between landowners. Landowners can also rent areas of LR under an environmental servitude regime. The third option is that landowners donate lands they own that are located within conservation units (thus helping the elimination of "illegal" land tenure).[160] Finally, they can register an area (of their own or of a third party) currently undergoing restoration or reforestation provided that it is in excess of the LR percentage limit and located within the same biome.

As a conclusion, the evolution of federal environmental policy and of the LR, its central measure, has been convoluted and it remains unclear whether the new status quo will last. Although Brazil may have one of the most advanced[161] forest legislations in the world, the numerous modifications have left cracks in the protection of native vegetation on private rural properties. One may wonder how many of these cracks were due to an "overly" ambitious legislation too disconnected from the ground, which constantly created room for opposition (either by landowners or environmentalists) and caused the appearance of modification proposals to reduce the scope of the rules.

Importantly, the legislation has shifted the criteria for locating and calculating the percentage of LR several times, leaving states like Mato Grosso in plain confusion as to the status of its vegetation. In 1965, the very vague criteria were that areas "north" of the Center-West Region should preserve 50% while areas to the "south of the Center-West should either protect 50% for new properties or 20% for already cleared ones. In 1989, the amendments to the FC specified a modification only for "Cerrado areas" which disrupted whichever vague boundaries pre-existed.

[160] This is ironic in a sense, since it equates to validating illegal practices (i.e. owning an area where it has never technically been possible to own one) to later eliminate the existence of these properties. A little like accepting the donation of fraudulent bills in exchange of reducing a debt.

[161] In the sense of "protective"

In 1996, the Temporary Measure n°1,511 introduced two new criteria and explicitly mentioned forest areas of the Legal Amazon. It specified that rural properties located in areas of "forest type" should preserve 80% of their area under LR. Areas of Cerrado saw their LR percentage increase to 35% in 2001. One may have expected that the new FC of 2012 would bring clarity to these vague boundaries which had created several misunderstandings and conflicts between federal and state agencies in Mato Grosso. However, Article 12 of the new FC does not mention any clear criterion, referring again to "areas" of forests, Cerrado, and other vegetation types, thereby missing the opportunity of using the any clear geographic boundary (e.g. ecological biomes). I do not mean to say here that this would be a better indicator of the type of areas to protect under the LR system. I am solely pointing out that the lack of clarity regarding the criterion to calculate LR results in more harm than good, since it opens the way for landowners to claim a reduced percentage of LR by claiming that their property belongs to the vegetation type least protected by the law. Had the legislators used the ecological biome boundary, this confusion would have been less likely. However, this would have probably resulted in reduced protection for forests located in the Cerrado vegetation areas. This lack of clarity allowed for several political battles to take place at the state-level. In Mato Grosso, rural landowners have been able to dispute the percentage applying to forests in Cerrado areas (also called "transition areas"), as demonstrated by the review of state environmental policies that follows.

4. ENVIRONMENTAL POLICIES AT THE STATE-LEVEL: THE PIONEERING CASE OF MATO GROSSO

4.1. A GRADUAL DECENTRALIZATION OF FEDERAL POLICY MARKED BY CONFLICTS

4.1.1. The State Environmental Code of 1995

While the federal environmental legislation was developing, states had to translate regulations into state law and implement them. Responsible for a third of the deforestation in the Legal Amazon by 2017 (INPE, 2018), the state of Mato Grosso has been the primary focus of federal concern about deforestation while concomitantly being at the forefront of anti-deforestation policies. In spite of adding obstacles to forest clearing on its own, the state of environmental legislation in Mato Grosso greatly suffered from the interaction between state-level and federal-level environmental policies which created several misinterpretations, especially around the status of transition areas. This review of the state-level articulation of environmental policies will examine this point, which is fundamental to possible legal misinterpretations by landowners.

The state first adopted its own State Environmental Code in 1995[162] translating the requirements of the 1965 Forest Code as well as its amendments of 1989. Importantly, it distinguished for the calculation of the LR percentage three different types of vegetation: Cerrado, forests, and transition forests.[163] Properties located in forests and transition forest areas were lumped up into a LR requirement of 50%, while properties in Cerrado areas would only need to conserve 20% in accordance with the 1989 FC amendments.[164] The Code also created the Unique Licensing System

[162] Complementary Law n°38 of November 21, 1995.
[163] Called 'matas de transição' in Portuguese (see Art. 62 §1 of Complementary Law n°38 of 1995)
[164] Properties located in areas of the Pantanal were however prohibited from any deforestation, except for subsistence agriculture

("Licença Ambiental Única" – LAU) that required prior approval of any type of rural land-use, something rather "ambitious" if demanded retroactively as such to all already settled landowners. As a result, at least theoretically (and legally), deforestation was only legal if (1) clearing was made within the legal limits in effect in the state (2) it had been licensed by the state through a LAU. Another impediment to deforestation was that landowners could only get the LAU if they had previously registered the percentage of LR with the local notary office following the *averbação* requirement of 1989. This system was never fully applied by landowners who complained about delays of several years, sometimes a decade, in the issuance of authorizations due to bureaucratic issues or, in some cases, their lack of legal land titles. Finally, the Code altered the mission of the pre-existing State Foundation for the Environment (*Fundação Estadual do Meio Ambiente* – FEMA) to serve as the administrative branch of the state's environmental policy and enabled it to pass agreements with federal agencies for purposes of deforestation control.

4.1.2. Decentralization and state initiatives to control deforestation

The decentralization of environmental and forest policy can be traced back to 1981, with the National Policy on the Environment (PNMA). This policy established the National System of the Environment (Sistema Nacional do Meio Ambiente – SISNAMA) which created a clear administrative structure for the implementation of environmental policy, specifying the competences of each level of governance (federal, state, municipal) and dividing policy implementation across the legislative (environment councils[165]), executive (IBAMA[166],

[165] At the federal level, the National Council on the Environment (Conselho Nacional do Meio Ambiente - CONAMA) and at the state level, the state councils on the environment (Conselho Estadual do Meio Ambiente - CONSEMA).

[166] Only created later in 1989 and replacing other institutions.

OEMAs[167], and municipal environmental agencies), and judiciary branches (Azevedo, Pasquis, and Bursztyn 2007). This movement toward the decentralization of environmental policy was especially marked by Article 24 of the 1988 Constitution which explicitly stated that the legislative competence in this regard was to be shared concomitantly by the federal state, the states, and the municipalities. The decentralization could however only occur had the states fulfill some important requirements, such as having a "state secretariat, a code, and a fund, in addition of a council, all specialized for the environment"[168] (Azevedo, Pasquis, and Bursztyn 2007: 45). The 1995 State Environmental Code of Mato Grosso had the purpose of fulfilling these requirements, since it also designated the FEMA as the state secretariat for environmental policy.

Decentralization took however a new impulse under the Pilot Program for the Protection of Tropical Forests of Brazil (PPG7[169]) funded by the European Union and the G7. Created in 1992 and administered by the World Bank, this plan supported the reinforcement of state capacity for the implementation of environmental and forest policies in Brazil (Scardua and Bursztyn 2003). This movement for decentralization, supported by the World Bank which saw the deforestation ensuing the construction of infrastructures, was furthered by the National Policy on Forests in 1998 which involved the state and municipal levels in the policy (Andrea Azevedo and Scardua 2006; Daugeard unpublished). As a result, by 2002, 18 Brazilian states had adopted their own deforestation policies, each having their own particular characteristics depending on local state capacity (Scardua and Bursztyn 2003). Mato Grosso was a pioneer in the development of

[167] State Body for the Environment (Orgão Estadual do Meio Ambiente - OEMA). This type of agency have different names depending on the states. In Mato Grosso, this OEMA is today the SEMA.

[168] Quote translated by the author. The original full quote in Portuguese reads as follows: "No caso, o estado e/ou município, para exercer a competência administrativa, deve ter uma secretaria, um código e um fundo, além de um conselho, todos ligados à área ambiental."

[169] Programa Piloto para a Proteção das Florestas Tropicais do Brasil – PPG7

decentralized structures for environmental policy. The willingness with which Mato Grosso adopted these new institutions can partly be explained by the high deforestation rates experienced by the state in the 1990s (henceforth creating a particular sense of urgency to control rampant deforestation) (Andrea Azevedo and Scardua 2006) and partly by the state's desire to have a hand on environmental policy (i.e. one of the major obstacles to its fast agricultural expansion), although it is difficult to determine which of these two concerns had most influence on the decentralization process.

Mato Grosso finally started to acquire significant power in environmental policy implementation following the federal pact (*Pacto Federativo*) transferring deforestation monitoring and enforcement competencies from the MMA to the FEMA in 1999. As a result, Mato Grosso pioneered a Rural Property Environmental Licensing System (SLAPR) as a way to control the compliance of landowners with environmental laws. Until then, the PRODES was unable to determine whether the observed deforestation was legal or illegal because the absence of a rural cadaster made it impossible to link a particular deforestation event to a specific landowner (Stickler et al. 2013). This system required landowners to declare the amount of APP and LR as well as the legal boundaries of their properties in a georeferenced document based on Geographic Information Systems (GIS) software (P. D. Richards and VanWey 2016). The program started by targeting the largest rural properties in the state with a criterion of 1,000 ha (Chomitz and Wertz-Kanounnikoff 2005). Unfortunately, after being lauded widely as a new-generation tool to fight deforestation, the efficiency of this system evaluated between 2000 and 2007 was seriously called into question because it had no significant impact on deforestation and even "legitimized"[170] part of it by

[170] As Azevedo (2009) puts it, the SLAPR ended up granting authorization for new deforestation instead of preventing it.

granting land clearing authorizations to landowners (Andréa Aguiar Azevedo 2009; Rajão, Azevedo, and Stabile 2012).

In 2000, landowners were allowed to compensate their LR deficit through forest restoration approved by the FEMA or through 'donating' an area they may have owned within Conservation Units (UCs) located within the state,[171] which effectively meant donating a fictive area to the state in a UC.[172] The possibility to compensate area was further expanded in 2002[173] to allow for natural regeneration or the purchase of areas still covered in native vegetation ecologically equivalent to the current one. In this sense, although deforestation was prohibited without prior authorization, landowners still had a way to circumvent the rules and regularizing their situation by later purchasing areas of native vegetation to compensate their LR deficit. Stickler et al. (2013) however note that this mechanism was barely used by landowners between 1999 and 2007 as the FEMA only validated 5 processes within this period.

The decentralization of the environmental policy from the federal to the state level continued in 2005-2006 despite the *Curupira* operation that terminated the FEMA in 2005 over allegations of corruption. A first step was the creation[174] of the State Environmental Agency (*Secretaria Estadual do Meio Ambiente do Mato Grosso* – SEMA-MT) to improve environmental policy management in comparison to its predecessor. The SEMA-MT was put in charge of compiling a geodatabase on all properties within the state and was responsible for providing the LAU. A second step was

[171] Ordinary Law n°7.330 of September 27, 2000
[172] As explained in Art. 5 of Ordinary Law n°7.868 of December 20, 2002, for any 1 hectare of degraded area, the landowner would need to purchase 1 hectare in Conservation Units.
[173] Ordinary Law n°7.868 of December 20, 2002
[174] Complementary Law n°214, June 23, 2005

the formulation of a state forest policy[175] which would lay the basis for the transfer of deforestation enforcement activities to the state level. A final step toward the decentralization of environmental policy was a cooperation agreement signed between the MMA and the SEMA-MT granting the latter the right to issue licensing for any type of deforestation clearing. Until then, it could only issue authorizations for clearings larger than 200 hectares (ha). This contributed to reducing the fragmentation resulting from the fact that policy enforcement is a shared competence between IBAMA's decentralized branch in Mato Grosso, and the SEMA-MT.

4.1.3. The MT-Legal program as a state-level illustration of the agricultural sector backlash

The increasing influence of the agricultural lobby over state environmental policy and politics[176] was somehow aggravated by the decentralization, which effectively reinforced the role of state politics on this type of legislation. An indication of this influence can be seen in the creation of the Mato Grosso Environmental Regulation program in 2008[177] (*Programa Mato-grossense de Regularização Ambiental* - MT-Legal). Despite the mixed success of the SLAPR and the low number of LAUs issued, the state created the MT-Legal to "find a solution" to the pervasive non-compliance of rural properties with environmental law. The objective was to require all landowners to register their property into an Environmental Rural Cadaster System (called CAR-MT)[178] as a first step toward obtaining the LAU. It was conceived of as an easier regularization

[175] Complementary Law n°233, December 21, 2005

[176] Although there is no unequivocal measure of it, one may note the arrival of Blairo Maggi (a very large-scale soybean producers, owner of the AMAGGI company) at the office of governor in January 1, 2003 where he will remain until 2010. Another one is the creation of the soybean producers association APROSOJA-MT in 2005.

[177] Complementary Law n°343 of December 24, 2008

[178] The georeferenced licensing CAR-MT system was the inspiration for and predecessor of the federal-level CAR introduced by the 2009 *Mais Ambiente* program and more officially established as the centerpiece of environmental policy with the 2012 Forest Code (FC). As a result of the subsequent adoption of a similar system at the federal level, the state of Mato Grosso had to adapt its system to the federal CAR when the 2012 FC was passed, requiring landowners to register again their property into a new system only a few years after the first one.

path to remove the embargos imposed on the numerous properties that had been fined for illegal deforestation. Landowners had therefore to register their property in a geodatabase, recording the GPS coordinates as well as the percentages of APP and LR of their property.

The MT-Legal however contained some very contentious points. First, landowners with a LR deficit had to sign a Behavior Adjustment Agreement[179] (Termo de Ajustamento de Comportamento – TAC) with the state, whichdetailed their plan to restore areas missing native vegetation cover. Landowners who had been previously fined for their non-compliance with environmental policies could see the total amount of due fines reduced by 90%[180] provided they followed through with the TAC. Importantly, the MT-Legal also provided landowners with a new way to regularize their LR deficit by paying a certain sum of money to the State Environmental Fund (Fundo Estadual do Meio Ambiente – FEMAM)[181]. This led some authors to conclude that it practically exempted landowners from any real responsibility for deforesting illegally before 2008 because they could essentially buy their way out[182] (Rajão, Azevedo, and Stabile 2012). In addition, the existence and legality of the FEMAM was rejected by the MMA (Stickler et al. 2013). The state's weak ability to effectively control whether the areas would be restored by landowners reinforced this perception. In a way, the MT-Legal responded to the urgency of landowners who would see their rural credit access removed by virtue of the Central Bank resolution of 2008. Since the agricultural lobby and state of Mato Grosso had been unable to lobby the federal government

[179] Art. 2, Complementary Law n°343 of December 24, 2008
[180] Art. 14, §2, Complementary Law n°343 of December 24, 2008
[181] Art 12. III b), Complementary Law n°343 of December 24, 2008
[182] For clarification, this formula is me writing, not the cited authors.

quickly enough to remove this measure, the MT-Legal was "the most rapid way to achieve the necessary flexibility for receiving the license and credit"[183] (Azevedo 2009: 272).

If the 2012 FC eliminated the possibility of excusing illegal deforestation up to 2008 by donating money into a fund (opened up by the MT-Legal program), it nonetheless excused deforestation prior to 2008 for landowners with less than 4 FMs. In addition, for landowners above 4 FMs, a fair amount of uncertainty remains about determining the date to apply for examining compliance with the FC. At least theoretically, landowners indeed do not have to restore or compensate their LR deficit if they were respecting the LR percentages *in effect* at the time they cleared. Determining this date is however complicated. In Mato Grosso, landowners developed the idea of an "acquired right" (*direito adquirido* in Portuguese) to land clearing, arguing that the applicable date at which the 80% LR in forested areas should apply is May 26, 2000 (corresponding to the date at which the Provisional Measure of 1996 was transcribed into state law). However, this legal interpretation by landowners is very uncertain and the SEMA does not necessarily interpret it that way. The issue is even more complex in presence of transition vegetation in the property of a landowner (see next section). Determining the period within which different forest conservation requirements applied is a wicked legal issue but has perhaps less importance than one may assume. Indeed, determining these periods for deforestation in the rural properties of each landowner of Mato Grosso is beyond the monitoring capacity of the SEMA. Rather, this issue has to be solved on a case-by-case (i.e. property-by-property) basis, and certainly only arises if or when a landowner opposes an environmental fine or asks for an environmental license to clear native vegetation.

[183] Original full quote in Portuguese "Como a movimentação política do estado junto ao Governo Federal para naular essa resolução não gerou resultado, o MT legal se revelou como forma mais rápida de fazer esse tipo de flexibilização para o recebimento da licença e do crédito" (Azevedo 2009: 272)

4.2. THE PROBLEMATIC REGULATION OF TRANSITION AREAS FOR THE CALCULATION OF LEGAL RESERVES

The fragmentation of environmental policy enforcement and interpretation in Mato Grosso yielded considerable misunderstanding about transition areas which represent a significant area of vegetation to be preserved in the municipalities of the study (**See Map 3.3.1**). The classification of such areas originated from the interpretation of a vegetation map established by the military regime under the RADAMBRASIL[184] project between 1970 and 1985. In practice, it seems that civil servants at the FEMA relied on several information sources including this map, the socio-ecological zoning maps of Mato Grosso, topographic maps of the IBGE, and satellite images gathered at the FEMA. Since all of these sources had different degrees of precision, the interpretation of which category of vegetation a property belonged to varied depending on which source was used or who was the technician conducting the assessment (MMA 2005). The RADAM classified three different types of transition areas: forest-forest, forest-Cerrado, Cerrado-Cerrado. The category of forest-Cerrado was the most problematic for complying with the FC since it often meant the presence of forests (Instituto Socio Ambiental and Instituto Centro de Vida 2006). Given the coarse resolution of the RADAM mapping (1:1,000,000), however, it was difficult to determine whether an area that appeared as transition on the map actually corresponded to forests on the ground, until a field visit was carried out (which most often was not the case). Unless otherwise noted, I used the word "transition" to refer to forest-Cerrado transition areas in the remainder of the text.

[184] Radar of the Amazon Project (in Portuguese: Projeto Radar na Amazônia). This mapping conducted between 1972 and 1974 by the military regime was the first "systematic inventory of minerals, soils, and vegetation ever attempted for the entire Brazilian Amazon" (Mahar 1979: 21)

Despite the State Environmental Code being very clear about the 50% LR percentage requirement for transition areas, the FEMA seem to have only required rural properties located in transition areas to register (*averbação*) a LR area of 20% until the 2000-2002 period,[185] in complete contradiction with the FC which required 80% for forest areas since the Provisional Measure of 1996 (Andréa Aguiar Azevedo 2009; MMA 2005). With the increase from 50% to 80% in LR percentage for forest areas operated by the Temporary Measure of 1996, this interpretation created an open conflict between the FEMA and the IBAMA. For the IBAMA, it was clear that properties located in these areas should have a LR of 80% since transition areas are forests. This diverging interpretation had very concrete implications since these two public bodies were sharing the burden of controlling deforestation policies' enforcement in the state, depending on the size of clearings. As noted by Azevedo (2009), deforested areas above 200 ha were under state decision-making between 2000 and 2005 while those below 200 ha were the enforcement responsibility of IBAMA until 2005. This distribution of competence between the state and federal agencies reinforced the idea that the FEMA could easily be under the influence of large landowners since it had less financial capacity than IBAMA. After the complete decentralization of Mato Grosso's environmental policy, all deforested areas fell under state enforcement in 2006. Logically, landowners may have been imposed with different limits based on the identity of the environmental policy enforcer visiting their property.

As a result of this conflict, the FEMA changed its policy to impose a LR of 50% to transition areas starting in the 2000-2002 period up until 2005 when the agency was terminated following

[185] Sources do not agree on the exact date at which the FEMA finally started to apply the percentage of 50% to these areas. Azevedo (2009) writes that the FEMA did not change the policy until the arrival of the Rural Property Environmental Licensing System in 2000, while the MMA (2005) notes that the FEMA only changed this policy after 2002.

widespread corruption scandals. From this moment on, only two vegetation classifications prevailed: Cerrado and forests.[186] Transition areas should have then been considered protected under an 80% LR, but (due to the variety of classifications for this type of vegetation) considerable uncertainty on the appropriate percentage remained, and percentages still varied on a case-by-case basis. A 2010 state law[187] attempted to address the confusion around the issue by clarifying what type of vegetation pertained to each category and the basis on which it should be assessed.

[186] In Portuguese, "Cerrado" and "floresta"
[187] Complementary Law n°382 of January 12, 2010

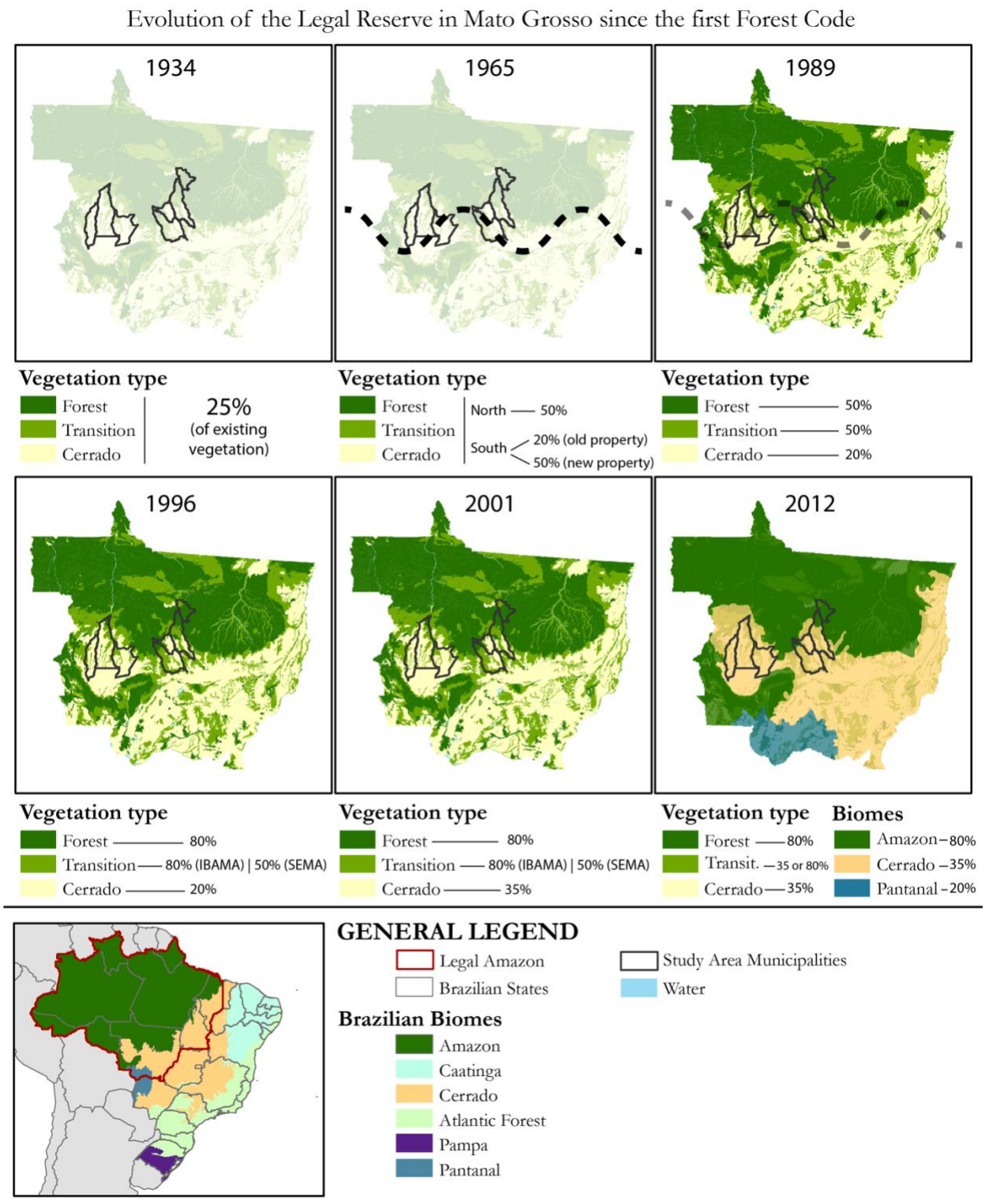


Figure 3.2. Evolution of the Legal Reserve (LR) percentage in Mato Grosso from the first Forest Code (FC) in 1934 to the new FC in 2012. **Note**: Although in technical terms transition areas are forests and should be following the 80% LR, the fact of whether a property is really located in a transition area has to be determined on a case-by-case basis. This is due to the fact that the original classification of transition areas was done by a 1972 military mapping project (RADAMBRASIL) with a gross resolution not helping to determine with precision which properties are included or not. This mapping may also have been subject to several classification errors. **Data**: Vegetation type is based on the

RADAMBRASIL dataset, and the classification is based on Fearnside and Ferraz (1995) and Fearnside and Barbosa (2003). I classified forest-to-forest contacts as forests, and Cerrado-to-Cerrado contacts as Cerrado, classifying only forests-to-Cerrado contacts as transition areas.

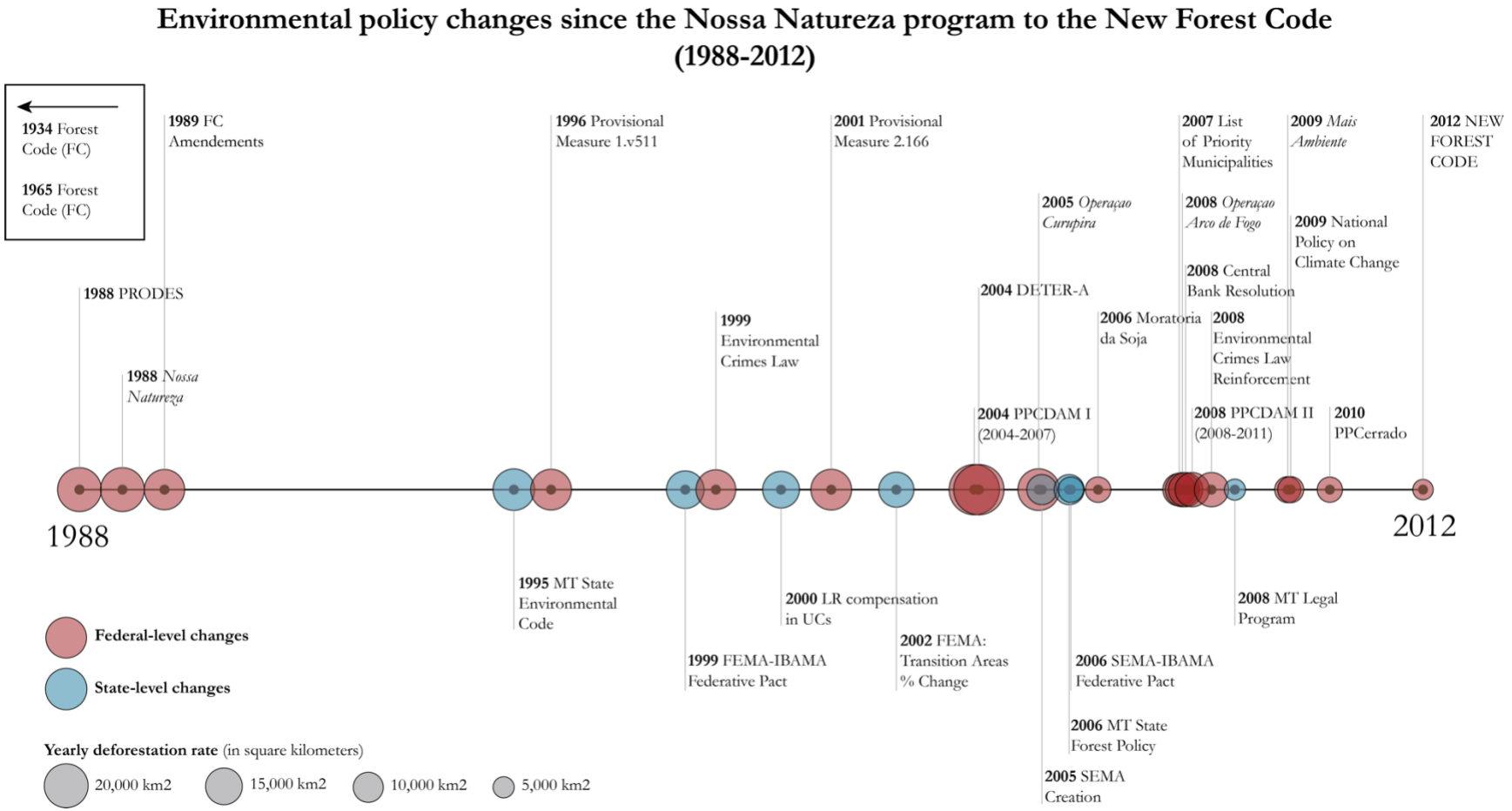


Figure 3.3. Environmental policy changes from the *Nossa Natureza* program (1988) to the new Forest Code (2012).

5. DEFORESTATION AND THE EFFECTIVENESS OF ANTI-DEFORESTATION POLICIES IN AMAZON-CERRADO TRANSITION AREAS OF MATO GROSSO

5.1. THE EVOLUTION OF DEFORESTATION RATES AT THE STATE-LEVEL

5.1.1. The dominant role of Mato Grosso in Legal Amazon deforestation

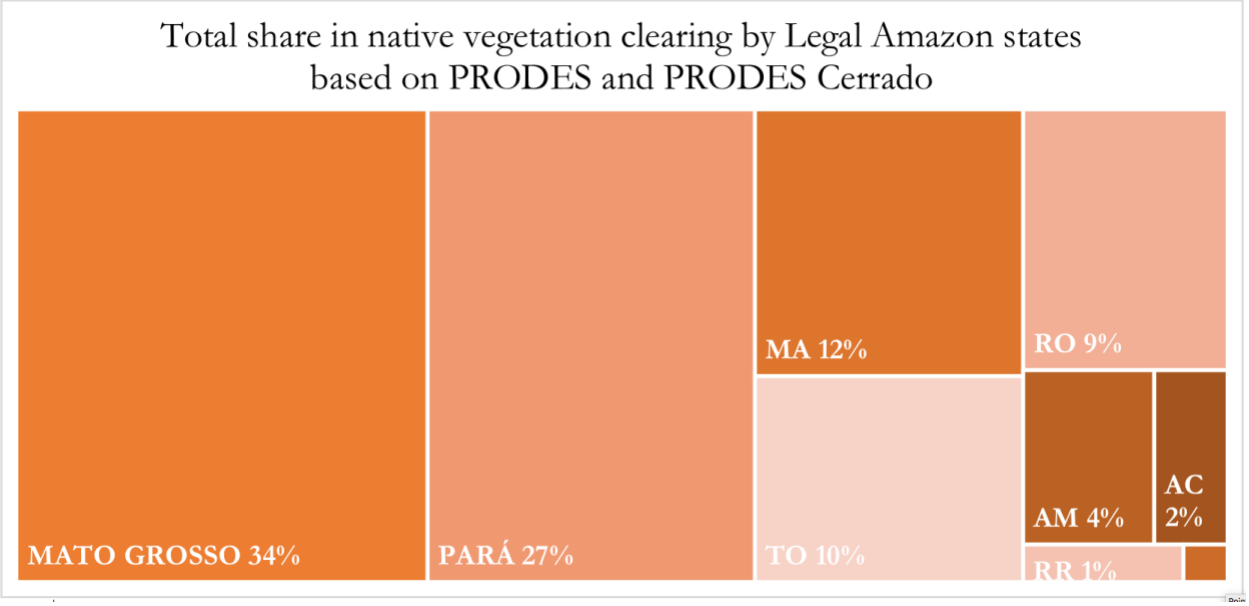


Figure 3.4. Historical contribution to native vegetation clearing (in cleared square kilometers) as estimated by PRODES and PRODES Cerrado. The lower-right rectangle is the state of Amapá, responsible for less than 1% of total deforestation. Abbreviated states: MA=Maranhão; TO=Tocantins; RO=Roraima; AM=Amazonas; AC=Acre; AP=Amapá. **Methodology:** See footnote.[188]

Mato Grosso has been historically responsible for the largest share of deforestation and land clearing in the Legal Amazon. Although PRODES deforestation estimates place Mato Grosso as the 2nd largest state in terms of deforestation (25.08%, or 173,938 square kilometers), right behind

[188] **Methodology for creating Figure 3.4.:** Deforestation data from both PRODES and PRODES Cerrado were used to create this figure. Since PRODES imperfectly captures deforestation in the Cerrado biome, only the data for the Amazon biome was included. To include data about deforestation in the Cerrado portion of the Legal Amazon, the data from PRODES Cerrado was used only for that area. This methodology helps avoiding double-counting of deforestation events since PRODES and PRODES Cerrado overlap partly. Note: Had the entire land clearing data for the Cerrado biome been included, this figure would likely look slightly different. Here it is only about the Legal Amazon area.

the state of Pará (37.78%, or 262,031 square kilometers), these estimates imperfectly account for the clearing of native vegetation in the Cerrado. Cerrado clearing is more diverse in terms of vegetation types[189] but this biome nonetheless represented a non-negligible area of forests considering that transition areas in both biomes originally represented 21.48% of the state's area.[190] and other vegetation. Once native vegetation clearing is included according to the latest data of the PRODES Cerrado,[191] the picture is very different as Mato Grosso becomes the state responsible for the largest clearing in the history of the Legal Amazon (33.96%, 329,323 square kilometers), with Pará following behind (27.02%, with the same clearing estimate than the PRODES since this state is located fully within the PRODES monitoring zone) (**See Figure 3.4**).

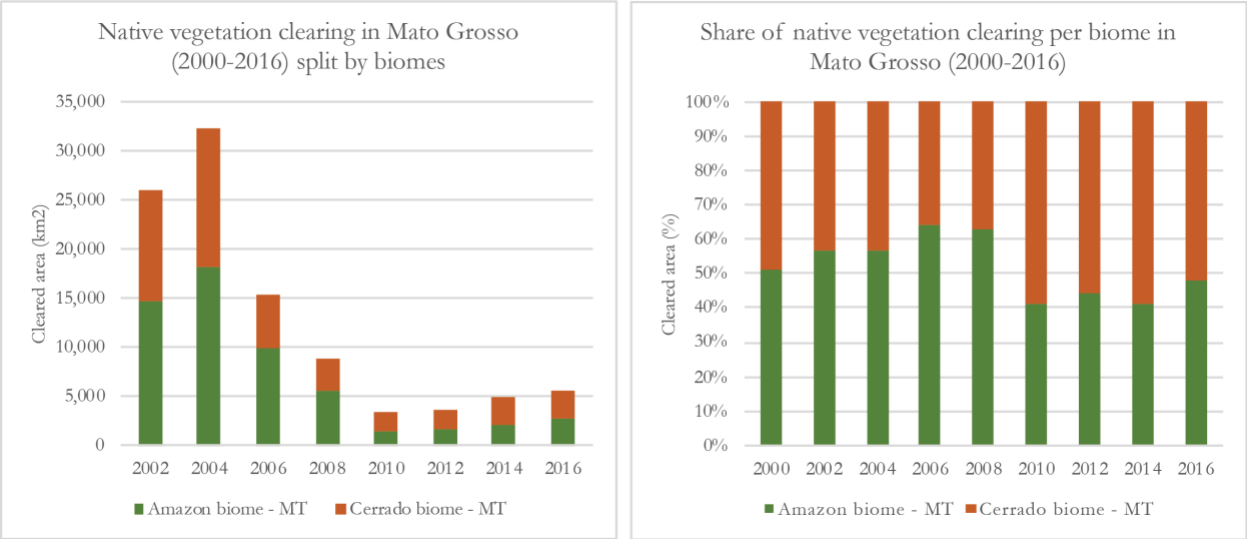


Figure 3.5. Two-year estimates of native vegetation clearing in Mato Grosso (2000-2016 period). **Data**: PRODES and PRODES Cerrado (INPE, 2018). **Methodology**: Similar methodology than Figure 3.4. **Reading**: green bars corresponds to deforestation in the Amazon biome while brown bars correspond to native vegetation clearing in the Cerrado biome. Example: the estimate of deforestation for the year 2004 correspond to deforestation occurred during the 2002-2004 period. **Acknowledgements**: the author would like to thank Dr. François-Michel Le Tourneau for assistance in preparing the data.

[189] By no means I imply here that the social and ecological implications of this clearing are similar.

[190] According to the vegetation classification of the RADAM based on Fearnside and Ferraz (1995) and Fearnside and Barbosa (2003), I found that transition areas represented 21.48% (194,329 km2) of Mato Grosso. Forest areas occupied 45.21% (409,019 km2) and Cerrado areas 32.64% (295,307 km2) of the 904,649 km2 covered by the state.

[191] Data produced by the INPE through the Environmental Monitoring of Brazilian Biomes Program (Programa de Monitoramento Ambiental dos Biomas Brasileiros), initiated in 2015 following a *portaria* of the MMA (nº 365 of November 27, 2015)

The **Figure n°3.5** above shows deforestation in Mato Grosso since the beginning of the 2000s by two-year periods. It appears that large quantities of native vegetation in the Cerrado biome portion of the state were cleared at the same time as were forests identified by PRODES in the Amazon biome. Although the two biomes are different in size, a higher proportion of the Cerrado biome has been cleared in Brazil. According to general estimates, in Brazil, around 18% of the Amazon forest's original cover has been cleared while the Cerrado had already lost 47.8% of its original cover by 2008 (MMA n.d.).

5.1.2. State-level deforestation drivers in Mato Grosso

Examining deforestation rates based only in forest areas,[192] it would seem that most land clearing in the state of Mato Grosso occurred before 2005 (**See Figure 3.1**), with two noticeable peaks around 1995 (10.4k km^2) and 2004 (11.8k km^2). These peaks were common to the entire Legal Amazon (which is not surprising since Mato Grosso has driven 1/3 of total deforestation) as Pará and Rondônia also experienced high deforestation rates the same year. Such peaks coincide with insertion of the Legal Amazon into global commodity markets starting in the 1990s. Although there is much debate about the causes of each deforestation surge, the first deforestation peak of 1995 can partly be explained by the increase in beef demand right after a period of limited deforestation due to Brazil's economic difficulties in the 1980s (Le Tourneau 2016). Some authors point out that the Amazon cattle industry has been historically responsible for two thirds of deforestation in the region (Nepstad, Stickler, and Almeida 2006). Others point out that the intensity of deforestation in the Legal Amazon picked up in the middle of the 1990s when rural credit was made widely available by the Constitutional Fund for the Development of the Center-

[192] The PRODES Cerrado does not allow us to make historical conjectures before 2000, the first date of land clearing mapped by the dataset.

West[193] (Fundo Constitucional de Financiamento do Centro-Oeste – FCO) which offered low-interest rate credit to farmers (Andréa Aguiar Azevedo 2009).[194] The *Plano Real* of 1994 put a halt to hyperinflation and stabilized the Brazilian currency, which in turn made land prices drop (as compared to their previously inflated price) offering new opportunities for land expansion (Fearnside 2005).

In the aftermath of the deforestation peak of 1995, and despite a temporary soybean price drop in 1997 and 1998, Amazon-Cerrado transition areas of Mato Grosso experienced high deforestation rates as compared to the rest of Mato Grosso, especially the BR-163 area and the Chapada dos Parecis. The soybean area in the state passed from 2m ha of planted area in 1994 to 5.3m in 2004, increasing 160% in 10 years. This area expanded both on forests and through the conversion of former pastures into cropland, a trend further reinforced by the gradual increase in land prices in the late 1990s. Deforestation was also highly correlated with rising soybean prices during the 1997-2004 period (P. Fearnside 2008). Morton et al. (2006) mapped the fate of land after forest conversion and found that direct conversion of forests to cropland amounted to more than 540,000 ha during the 2001-2004 period. The mean size of deforestation polygons for cropland was double that of pastures, and cropland conversion peaked at 23% of all deforestation in 2003 in Mato Grosso. The high soybean price of the early 2000s resulted in the "euphoria" of some landowners who cleared forests even in sandy areas unfit for soybean production (Andréa Aguiar Azevedo 2009). Cattle-ranching nevertheless remained the dominant land-use after forest

[193] Created by Law n.º 7.827 of September 27, 1989

[194] The state of Mato Grosso is uniquely placed to capture financing from various funds. Being part of the Center-West area, it is eligible to FCO financing. In addition, being located in the Legal Amazon and having a substantial share of the Amazon biome, it can also claim funding from the Amazon Investment Fund (Fundo de Investimentos da Amazônia – FINAM). The state is therefore very 'well-served' by federal transfers as compared to other states.

conversion, with crop expansion representing only 10% of deforestation in the 2001-2005 period (Macedo et al. 2012).

The second deforestation peak in 2004 thus occurred against a backdrop of high soybean and beef prices combined with an advantageous exchange rate for exports. Mato Grosso had a prime role in this deforestation surge as the state accounted for 76% of all deforestation that year (Andréa Aguiar Azevedo 2009). The **Figure 3.6** depicts part of the interactions between deforestation rates and the economic indicators, revealing -among others- the role that the exchange rate between U.S. dollars (U.S.$) and Brazilian reais (R$) played. The exchange rate is key to understand such interactions since it is sometimes a better proxy to assess the profitability of soybean and beef production in Mato Grosso, the majority of which are turned toward export markets (P. D. Richards et al. 2012).[195] For instance, in spite of lower soybean prices in 1997 and 1998, the exchange rate increase[196] compensated for some potential losses for farmers exporting soybeans, explaining in part why the deforestation rate did not decline dramatically during those years.

Deforestation rates collapsed after 2004 following the drop in commodity prices (after an 'overheating' period) (Pires 2014), the drop in the exchange rate, and with the enactment of the PPCDAm. Despite this, Morton et al. (2006) point out that deforestation in the BR-163-region remained high throughout 2003, 2004 and 2005. The drop may also have been the result of a severe crisis in the soybean sector which experienced higher transport costs (rising oil price), new costly

[195] Soybeans tend to be fully exported while beef is also destined to the domestic market

[196] I am referring here to the USD – BRL exchange rate. When it increases it is advantageous to farmers who receive their revenue in dollars because they are able to convert them in more reais than before. Although such increases of the exchange rate are seen positively by the farmers and the export sector, it is what a country would consider negative since it means that the national currency is weakening.

pests (such as the Asian soybean rust appearing in 2003) and a drought in the 2004-2005 year (Andréa Aguiar Azevedo 2009). Macedo et al. (2012) found that the improvement of soybean prices and restoration of soybean profitability (as compared to pre-crisis levels) after 2006-2007 did not lead to an increase in deforestation. This led the authors to conclude that there was a de-correlation or decoupling between deforestation and soybean and beef prices after the 2004-2008 period. This phenomenon shown on **Figure 3.6** is proof for some authors that public policies occurring during that period had an impact on land-use change in the Amazon (Nepstad et al. 2014; Gollnow and Lakes 2014).

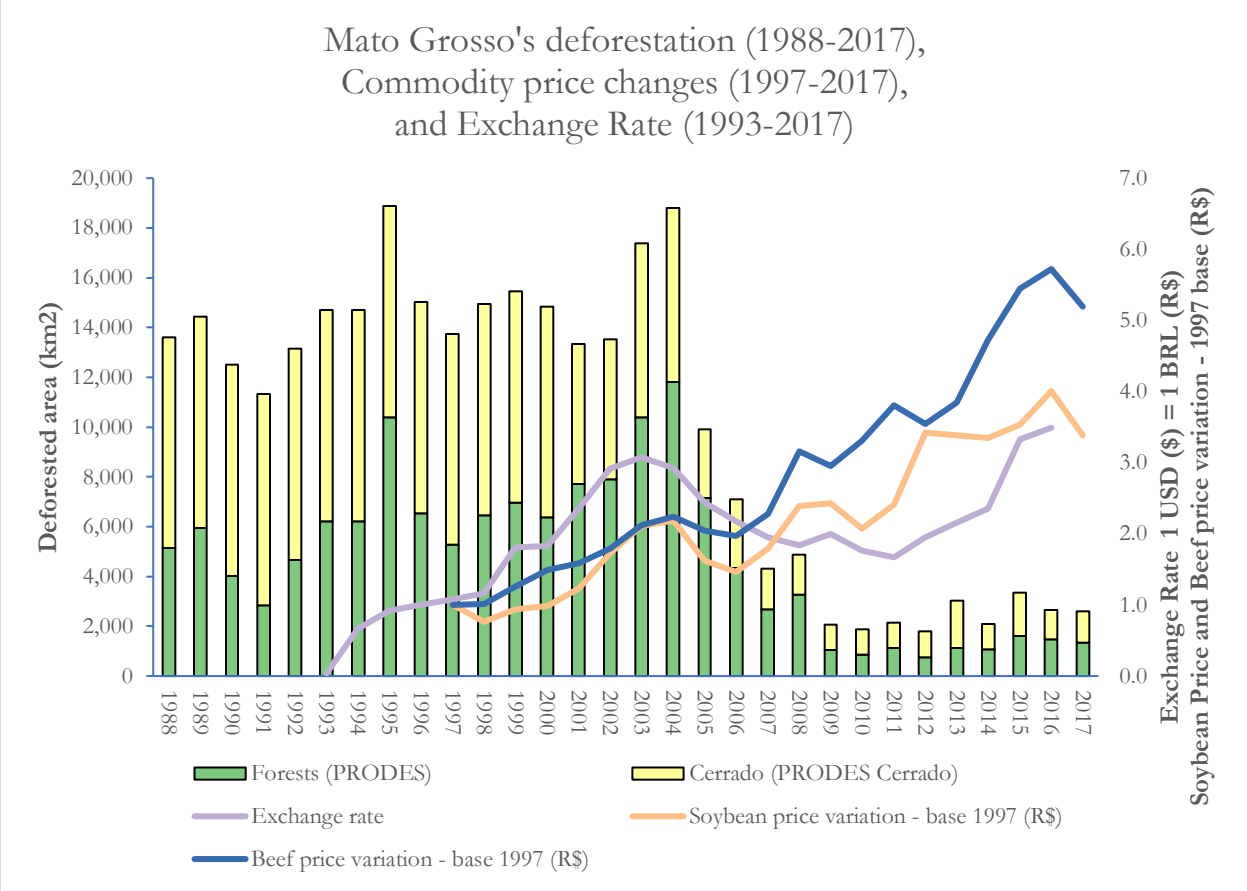


Figure 3.6. Deforestation rates in the state of Mato Grosso (in square kilometers) between 1988 and 2017 **Data**: deforestation rates based on PRODES data (for the Amazon biome) and PRODES Cerrado (for the Cerrado biome). Exchange rate between $1 (USD) and R$ (BRL) based on World Bank data. Variation base 1997 of soybean export prices at the port of Paranaguá (in the state of Paraná) and beef prices (R$) based on CEPEA-ESALQ data. **Note**: Since no data were available about Cerrado clearing before 2000, the initial mapped area of cleared Cerrado first available for 2000 has been divided for all the years before 2000 back to 1988 to facilitate the comparison with the PRODES data. Importantly, this significantly limits the interpretation of trends before 2000, because it cannot allow for the identification of land clearing peaks occurring in the Cerrado portion of the Legal Amazon.

Given the decrease in deforestation rates post 2005, it is necessary to discuss the effectiveness of environmental policies since they started to matter significantly around that time. The next section covers the role of environmental policies in deforestation rates in Mato Grosso, and especially in the Amazon-Cerrado transition areas which are the focus of this study.

5.2. THE IMPACT OF ENVIRONMENTAL POLICIES IN THE AMAZON-TRANSITION AREA OF MATO GROSSO

There has been a lot of debate about the role of soybean expansion in driving deforestation rates during the period both preceding and subsequent to the environmental policies of 2004 and 2008. Central to this problem is the fact that the agricultural frontier in Mato Grosso sits between two different ecological biomes (the Amazon and the Cerrado), the former being more explicitly monitored than the latter at the time policies were enacted. In addition, because the bulk of soybean production took place mostly in the Cerrado areas, a large part of the land clearing it caused may have been underestimated as **Figure 3.6 shows** (Brannstrom et al. 2008; Philip M. Fearnside 2001). Hence, several conclusions of the literature about the impact of environmental policies in the Legal Amazon may or may not be valid when looking closely at these areas. Most of my study area is located in the Cerrado biome, except for Sinop and Sorriso: Sinop is completely located within the Amazon biome while the northern part of Sorriso corresponds to the beginning of this biome (**See Figure 0.3**). I first review the literature on the effectiveness of federal environmental policies and then proceed to review (in a second part) the role played by zero-deforestation initiatives launched by the private sector.

5.2.1. A policy effectiveness mostly assessed in the Amazon biome

The review of the history of environmental policies should have now made clear that environmental policy changes did not have much of an impact prior to the enactment of the PPCDAm in 2004. Yet, landowners (at least in Mato Grosso) received signals that deforestation would not go unsanctioned by the government as early as 1988, with President Sarney's *Nossa Natureza* program, the creation of the PRODES, and the requirement in 1989 to register a 20% LR in the land title (*averbação*). In practice, it is difficult to assess with whether such signals were

effective because the data available on deforestation for this time period lacks accuracy. One can also speculate that such initiative was not meant to have much implications on the ground, but rather demonstrate the "concern" of the government for the subject at a time of increased international and national concern. For instance, the creation of the PPG7 in 1992 demonstrate that concern for the destruction of the Amazon rainforest. Whether these "early" policy changes avoided some clearing or, on the contrary, encouraged more deforestation as landowners perceived the end of a period of impunity remains an empirical question.

Few studies have evaluated the compliance with the Forest Code (FC), and authors doing this have exclusively focused on the Amazon biome. Stickler et al. (2013) have examined the compliance of private rural properties of Mato Grosso with the FC at different time periods, evaluating compliance both at the property-level (i.e. using a partially complete database on rural properties made available by the INCRA) and at the sub-basin level (i.e. taking river sub-basin boundaries as if they were private property boundaries) based on the area. They paid specific attention to the compliance of two different versions of the FC: the 1989 amendments to the FC with a LR of 50% for forests and the 1996 Provisional Measure with a LR of 80%.

From 1997-2001, the compliance with the 1989 FC was average (50% for sub-basins and 49% for properties[197]) while in the 2005-2009 period, the compliance with the 1989 BFC[198] had dropped down to 45% for sub-basins (instead of 50% previously) and to 30% of properties (instead of 49% previously). In contrast, during the same period, compliance with the new requirement of 1996

[197] Percentage referring to the share of total properties complying with the FC. This percentage drops down to 39% if we consider the total area covered by these properties complying with the FC instead of how many of them comply.
[198] No longer applying but used as a reference for comparison between periods

was medium to low (12% for sub-basins and 33% of properties[199]) while in the 2005-2009 period, only 10% of sub-basins, and 16% of properties were complying. The authors concluded that there was no evidence that "changes to the BFC to make it more restrictive (80% versus 50% LR) inhibited deforestation. In a full compliance scenario with the 1996 MP, there should have been 22,000 km2 of possible deforestation. However there has been much more, suggesting that the change did not have an impact" (Stickler et al. 2013: 8).

If the 1996 Provisional Measure did not have any impact, a large number of authors acknowledged the role of the PPCDAm in 2004 and 2008 in decreasing deforestation rates, along with the restrictions on rural credit and the "blacklisting" of Legal Amazon municipalities (Nepstad et al. 2014; Assunção et al. 2013; Assunção and Rocha 2014; Assunção, Gandour, and Rocha 2015; Pires 2014; Gollnow and Lakes 2014; Arima et al. 2014a; Macedo et al. 2012; Börner et al. 2014; Cisneros, Zhou, and Börner 2015; Le Tourneau 2016). Other authors have explored the role of private initiatives such as the soybean moratorium, yielding mixed conclusions about their effectiveness (Gibbs et al. 2015; Kastens et al. 2017; B. F. T. Rudorff, Adami, Aguiar, Moreira, Mello, Fabiani, Amaral, Pires, et al. 2011; Lambin et al. 2018). In fact, it has proven difficult, if not impossible, to disentangle which of the policy measures passed in the 2000s resulted in behavioral change in the Amazon as each measure probably had some effect. There are simply too many policy "cutoff points" to allow for a policy analysis study that would identify the respective role that each policy played. In addition, such policies were enacted at a time when market conditions were changing and becoming less favorable, casting doubts about whether the downward deforestation rates were the entire product of policies.

[199] Only 9% of the area covered by these properties was in compliance, suggesting that a majority of the farms complying with the FC were small farms

An important aspect of federal policies is that their enforcement was both intentionally and involuntarily uneven. Some areas, such as municipalities included in the list of Priority Municipalities (or "blacklist") were subject to more enforcement activities and fines than others. On the other hand, command-and-control enforcement also varied based on the transportation distance and costs of IBAMA teams, which greatly determine the logistics of enforcement operations (Börner et al. 2014). Assunção and Rocha (2014) assessed the efficacy of the municipality "blacklist" of 2008 which included 36 municipalities[200] responsible for 45% of deforestation in the Amazon biome. The authors found that 11,359 km2 of clearing was avoided during the 2008-2011 period largely thanks to stronger monitoring (as measured by the number of fines) and enforcement activities in blacklisted municipalities as opposed to non-blacklisted ones. Other studies have found more conservative estimates ranging from 2,304 to 10,653 km^2 of avoided clearing in the 2009-2011 period (Arima et al. 2014b) or 600 to 6,750 km^2 in the 2008-2012 period (Cisneros, Zhou, and Börner 2015).

Interestingly, Assunção and Rocha (2014) did not find that being included in the blacklist caused any changes in the availability of credit, yet this was a key piece of the legislation enforcement teeth. It is indeed puzzling that the authors did not find a reduction in the availability of rural credit since each fine is supposed to lead to an embargo of a property, barring access of that property to credit.[201] This suggests either that credit policies were not enforced as they should have been, or

[200] As compared to 547 municipalities partly or totally embedded in the Amazon biome

[201] As such, the larger amount of fines found in blacklisted municipality (1,206 more than in non-blacklisted municipalities) should have been accompanied declining access to rural credit, had the credit policy been implemented.

that landowners were indeed sanctioned but found other ways to access rural credit (by using someone else's name for demanding credit).

Arima et al. recognize that the attribution of deforestation reduction to the PPCDAm (in its second phase, 2008-2011) happened "against a background of ongoing reduction, attributable to other long-standing policies (e.g. adherence to the forestry code)." The results they found about the blacklist of municipalities thus represent a "lower bound to the impact of policy, overall" (Arima et al. 2014b: 470). As a result, the effect of federal policies at large may be underestimated. Examining the impact of federal policies for most Amazon biome municipalities, Hargrave and Kis-Katos (2013) found that a 1% increase in imposed fines would likely reduce deforestation by 0.2%, although most authors recognize the limit of stating the existence of a linear relationship between the two variables.

The real efficacy of the PPCDAm for the rest of the Legal Amazon has however been seriously called into question when it became known that fewer than 1% of the fines imposed by IBAMA had actually been paid by sanctioned landowners in the 2005-2010 period (Vialli 2011; Börner et al. 2014). The fact that the studies about the municipality blacklist found monitoring activities (as measured by the number of fines issued) effective leads one to think that a large aspect of the policy efficacy has been the perception by landowners of upcoming fines rather than the actual sanctions. In particular, authors have had difficulties controlling for the spillover of policies and the possible increased perceptions of farmers not directly targeted by the municipality blacklist of potential sanctions (Arima et al. 2014b). Authors have thus examined the possibility that it is not so much the fines but the IBAMA field site inspections and their associated consequences (e.g.

embargo, credit restrictions) that have caused deforestation rates to drop. Examining the effect of more than 15 thousand GPS coordinate points of inspections, Böner et al. (2015) found that inspections were particularly effective against deforestation events over 20 ha (considered large-scale) but not against small-scale deforestation (below 20 ha). Nonetheless, they note that it "seems that inspections have not generally resulted in lower deforestation in subsequent years and that differences in effect size may exist between states" (Jan Börner et al. 2015: 14). The authors hypothesize that differences may occur at the state-level and depends on how rigorous state institutions are in their willingness to enforce associated restrictions on credit and commercialization. This reinforces the assessment that policy enforcement has been uneven.

Routine and targeted fines (in blacklisted municipalities) were indeed not the only policy instrument. The Central Bank resolution to restrict credit has also proven to be an efficient enforcement mechanism, especially since the availability of rural credit had been identified as a potential driver of land expansion in the late 1990s. In a study, Assunção et al. (2013) found that R$ 2.9bn of rural credit were not allocated between 2008 and 2011 as a result of this policy, reducing deforestation by 15% during this period. As seen in another study by Juliano Assunção and Romero Rocha mentioned above, there were however no major differences in credit availability between municipalities included in the deforestation blacklist and those that were not, suggesting that the inclusion on the blacklist did not strengthened credit restrictions (Assunção and Rocha 2014). The fact that these authors found that the blacklist had an effect on the overall level of fines in a municipality suggest that there may be a disconnect between fines and embargos on the one hand, and whether banks imposed credit limitations on the other.

The effect of the policies was however distinctive from and additional to the changes in commodity prices. Assunçao et al. (2015) found that commodity prices greatly influenced the deforestation rates in the 2000s, and especially their drop after 2004. However, both the 2004 and 2008 PPCDAm also had an impact on deforestation rates from 2005 through 2009. Based on projections of what would the clearing have been in absence of the policies between 2005 and 2009, the authors found that these policies effectively avoided 56% of the total clearing that would have occurred during that period.

Besides fines and other command-and-control effects (e.g. fieldsite inspections, credit restrictions, etc.), some had hopes that the registration of properties into environmental cadaster systems like the CAR would help reduce deforestation. Mato Grosso pioneered such systems with the creation of the SLAPR in 2000. Azevedo (2009) and others have conducted an extensive review of the SLAPR system and concluded that, although it had been recognized as a 'best practice' by many, this system did not effectively reduce deforestation and, quite the contrary, permitted more deforestation than would have occurred had such a system been inexistent, notably by facilitating the delivery of authorizations for large-scale (legal) land clearing by the state agency (Andréa Aguiar Azevedo 2009; Rajão, Azevedo, and Stabile 2012).[202] The same went for the CAR during some time, as Gibbs et al note: "in 2014, for example, nearly 25% of Amazon deforestation in Mato Grosso and 32% in Pará occurred within registered properties" (Gibbs et al. 2015: 377). Later studies have however shown that the CAR would have helped reduce deforestation by 10%

[202] Rajão, Azevedo, and Stabile note that the SLAPR "(…) facilitated an increase in the total amount of deforestation by authorising legal clearings on a large scale. This strategy, along with others, adopted by farmers in association with local political actors indicates an act of 'institutional subversion', whereby SLAPR's outcomes were contrary to the expectations of the funding agencies and other actors who supported the project" (Rajão, Azevedo, and Stabile 2012: 241).

although such benefits are intrinsically linked to the evolution of related environmental policies (Alix-Garcia et al. 2018).

5.2.2. Supply-chain initiatives: the Soybean Moratorium and the "Beef Moratorium"

Aside from policy interventions, several changes intervening in commodity supply chains (beef and soybean) and obtained through public lobbying campaigns by NGOs have yielded positive outcomes in the Amazon (Nepstad et al. 2014; Massoca, Delaroche, and Lui 2017). However, many of these public-private initiatives across the world face considerable limitations due to their inability to control for leakage of deforestation (outside their scope of application) and their impact is often difficult to evaluate because of a lack of transparency and traceability (Lambin et al. 2018).

In 2006, the largest soybean traders[203] in the country passed an agreement with several NGOs (e.g. Greenpeace) and the MMA (which later joined in 2008) called the Soybean Moratorium (SoyM) in which they committed not to source soybean grown on areas of native vegetation cleared after 2006[204] (Rausch et al. 2016).[205] This initiative followed a 2006 report by Greenpeace titled *Eating up the Amazon* which uncovered the existing links between the soybean supply-chain and European consumers of fast-food and supermarket multinationals (e.g. McDonald's). These companies were singled out for sourcing beef and chicken fed with soybean-based diets, the bulk of which came from Brazil.

[203] Most soybean exporters are gathered within the ABIOVE or ANEC, which represents companies like Bunge, ADM, or Cargill.

[204] The cutoff date for compliance with this agreement is now 2008, following agreement among the members that this date should be aligned with the cutoff compliance date to the 2012 Forest Code which uses July 22, 2008.

[205] Importantly, no soybean producer association ever signed the agreement

Typically, the monitoring of soybean producers in violation of this agreement is conducted first by satellite analysis using the PRODES database (for deforestation polygons) and the MODIS sensor aboard Landsat satellites (for detecting crop presence). Once the monitoring system identifies deforestation polygons more recent than 2008 overlapping with crop production in a rural property (through visual interpretation of the satellite image[206]), a field visit is necessary to determine the owner of the area. The landowner in question is put on a "blacklist" managed by the Soybean Working Group (consisting of public-private partners to the SoyM, also including NGOs) which soybean traders consult prior to a purchase (Gibbs et al. 2015). The SoyM also includes in the blacklist producers who received a fine from IBAMA and whose property has been embargoed.

Studies have established the influence of this moratorium in avoiding further deforestation by demonstrating that little soybean-related deforestation is now occurring in the Amazon biome. Rudorff et al. (2011) found that in the 2009-2010 crop year, a mere 0.25% of all deforested areas in the Amazon biome had been planted with soybeans while Gibbs et al. pointed out that "in the 2 years preceding the agreement, nearly 30% of soy expansion occurred through deforestation rather than by replacement of pasture or other previously cleared lands" (Gibbs et al. 2015: 377). Although the SoyM represents valuable support to the enforcement of environmental policies, their criteria of application are different. The SoyM only applies to the portion of the property not complying with the agreement whereas IBAMA fines for FC violations leading to the embargo of the entire property. The effects of the SoyM can be limited and circumvented in three different ways: (1) since landowners own multiple properties, they can claim that soybeans come from the property not infringing the SoyM or the one that does not have an embargo; (2) soybeans can

[206] In the past, the verification procedure involved an airborne verification (i.e. by plane) to confirm the presence of soybeans

originate from a property rented and not owned by the landowner; (3) landowners can decide to keep deforesting and turn such areas into pastures for cattle, relying on crop-livestock integration techniques (Rausch et al. 2016). The latter possibility is also referred to as on-property leakage of deforestation. Studies have also pointed to leakage at the South American continent scale, saying that the SoyM and other anti-deforestation policies have not altered the pattern of soybean expansion in the continent (le Polain de Waroux et al. 2017).

Another supply-chain initiative affecting landowners in Mato Grosso and in the study area, but to a lesser extent, is referred to as the "Beef Moratorium" (BeefM). This initiative started in the state of Pará when the Federal Public Prosecutor's Office (*Ministério Público Federal* – MPF) sued slaughterhouses for sourcing beef coming from illegally deforested areas in 2009 (the so-called *Carne Legal* operation). The MPF offered slaughterhouses and ranchers a bargain by having them sign a Terms of Adjustment of Conduct (Termo de Ajustamento de Conduta - TAC). The four main slaughterhouses at the time (JBS, Bertin, Marfig, Minerva) signed an agreement with the MPF (hereafter "MPF-TAC") and committed not to source beef from properties which deforested beyond the 20% authorized by the FC. Following this example, other states in the Legal Amazon adopted the same method and the agreement now includes two thirds of federally-inspected slaughterhouses (Gibbs et al. 2016).

Following another report from Greenpeace (titled *A farra do boi na Amazônia*) in June 2009, a separate Zero-Deforestation Cattle Agreement was designed to include 129 meat-packing companies (including the three signatories of the MPF-TAC) which together represented 38% of the meat-packing capacity of seven Legal Amazon states (Massoca, Delaroche, and Lui 2017). In

contrast to the MPF-TAC (*Carne Legal* operation), the agreement focused on avoiding not only illegal deforestation but also any new deforestation (even legal). An assessment of both initiatives has demonstrated that meat-packing companies are now avoiding sourcing beef from properties with illegal deforestation (Gibbs et al. 2016). Nonetheless, the study pointed out the weaknesses of the agreement due to its limited scope and the existence of multiple avenues for circumventing the rule (such as moving cattle from a non-compliant ranch to a compliant one before bringing them to the slaughterhouse).

Overall, supply-chain initiatives provide a welcomed complement to environmental policies but could not really exist without them since they rely heavily on the state and its monitoring tools. By no means could such initiatives replace them, however, since one landowner may comply with supply-chain initiatives but not the federal- and state- policies.[207] In a review of the landowners' compliance in the Amazon biome with both the SoyM and the FC, some authors concluded that "82% of the sampled properties have not deforested since 2008, thus complying with the soy moratorium. However, approximately 65% out of these 82% are noncompliant with Forest Code legal reserve requirements" (A. A. Azevedo, Stabile, and Reis 2015).

5.3. THE EFFICACY OF ENVIRONMENTAL POLICIES HINDERED BY SPATIAL SPILLOVERS: SOYBEAN EXPANSION AND INDIRECT LAND-USE CHANGE

The efficacy of public policies and supply-chain initiatives in slowing soybean expansion into the Amazon biome is sizeable. Above all, the main impact of strengthened policies was to artificially create land scarcity by restricting possibilities of land-use expansion over forests

[207] However, an effort is made to integrate approaches as soybean exporters are supposed to also sanction landowners who have an embargo imposed by IBAMA.

(Thaler 2017). As a result, soybean production increased mostly through yield increases and by expanding on former or degraded pastures. Agricultural intensification through the adoption of no till and double-cropping systems improved farm rentability without a corresponding increase in area expansion (Arvor et al. 2012; VanWey et al. 2013). Before the reinforcement of environmental policies in 2004, intensification may have had an ambivalent role on deforestation rates since it increased the profitability of farming the frontier. As Gibbs et al. (2015) demonstrate however, the direct conversion of forests by soybean expansion reduced dramatically in the Amazon biome across all states after 2004 and after the SoyM. The effect on the Cerrado biome however is ambiguous as deforestation first reduced and later increased in the following period. The impact of increased soybean production on the conversion of forests remains moderate if one considers that soybean production in Mato Grosso increased 247% between 2000 and 2017, passing from 8 m tons to 30 m tons.

Such results are nonetheless obscured by their involuntarily induced effects on deforestation elsewhere. Many authors pointed out that the expansion of soybean cultivation over former pastures had the indirect effect of displacing low intensity cattle-ranching activities further into the Amazon (P. Richards 2015; Arima et al. 2011; Barona et al. 2010). Some authors found evidence that this Indirect Land-Use Change (ILUC) effect may have caused extensive deforestation. Using a counterfactual scenario, Arima et al. found that "a 10% reduction of soy in old pasture areas would have decreased deforestation by as much as 40% in heavily forested counties of the Brazilian Amazon" (Arima et al. 2011: 2). This means in practice that available land-use data proves that soybean expansion on former pastures was correlated with pasture expansion elsewhere. Field-based evidence (through interviews in Mato Grosso and Para) collected by some

researchers have not completely supported the idea that some agents (i.e. cattle-ranchers) do move from old consolidated frontiers to newer ones after either voluntarily leaving or being pushed away by soybean expansion (P. Richards 2015).

6. CONCLUSION: THE UNCLEAR IMPACT OF ENVIRONMENTAL POLICIES IN THE CERRADO

The review of the Brazilian environmental policy framework as it relates to deforestation in the Legal Amazon has depicted a convoluted system characterized by instability in the rules. In less than 16 years (1996-2012), private rural landowners have seen the rules applying to the required percentage of LRs change multiple times, depending on their location and the type of vegetation cover on their property. Without a doubt, some landowners may have taken advantage of this instability and profited from the lack of clarity in the rules. The associations representing farmers also heavily lobbied the state and federal government to induce some of these changes. Others however did suffer from this instability, causing a lack of stable planning horizon and uncertainty about which rules to respect, often leading to frustration and misunderstanding when fines were applied by IBAMA or the SEMA. It is thus particularly difficult to assess whether landowners took the reinforcement of environmental policies seriously or whether enforcement actions of environmental bodies lost credibility. Quite logically, this created two types of reactions: the wait-and-see strategy and the opportunistic one. Unfortunately, history rarely rewarded the group following the former strategy and rather made right the ones who took advantage of uncertainty to clear more area. Some authors refers to this as a reward for "cunningness" (Santiago et al. 2017).

The environmental policy history for both Brazil and the state of Mato Grosso reviewed in this chapter also suggests that Mato Grosso had greater institutional capacity in enforcing

environmental laws than most Legal Amazon states, reinforcing artificial land scarcity as an obstacle to agricultural expansion over forests. Although federal monitoring and enforcement of environmental policies strengthened starting in 2004, the state of Mato Grosso had already taken steps to target large-scale landowners since 2000, most notably by forcing them to register the amount of forest cover on their property into an environmental cadaster (the SLAPR). At lower levels of governance, some municipalities also had a proactive role in encouraging landowners within their administrative boundaries to comply with laws, as the example of Lucas do Rio Verde demonstrates (Rausch 2013). However, the political will to reduce deforestation may have been lacking as the counter-productive results of the SLAPR, leading to more deforestation, and the arrival of Blairo Maggi (large soybean producer) as state governor in 2002 may have indicated.

There are still obscure areas in the evaluation of environmental policies' effectiveness. Since the PRODES is the most commonly used dataset for environmental policy analysis studies, and since it only imperfectly captures native vegetation change in the Cerrado, most assessments have not provided any serious treatment of FC compliance in the Cerrado. Therefore, we have limited knowledge about whether environmental policies had any impacts in these areas representing the bulk of soybean production. What we know for sure is that 65% of all soybean expansion in the Cerrado area of MATOPIBA took place over native vegetation, pointing out to a limited presence or effect of policy enforcement there (Trase 2018). Additionally, despite an extensive discussion about which policy mechanism was most effective in the Amazon biome, the literature has not as extensively examined which policy mechanism may have played a role there. It is thus a contribution of this dissertation to document how the behavior of large-scale soybean producers in

the Cerrado portion of the Legal Amazon was affected (or not affected) by environmental policies, a topic that I address in the next chapter.

Chapter 4. Land clearing trajectories of Mato Grosso's soybean producers

1. THE NEED FOR AN UNDERSTANDING OF PROPERTY-LEVEL LAND CLEARING PATTERNS

The previous chapter (Chapter 3) has helped clarify the overall pattern of deforestation at the state-level and in the transition areas of Mato Grosso. Despite being exposed to less policy pressure than their counterparts in the Amazon biome, the contribution to deforestation rates by soybean-production areas dropped down significantly since the mid-2000s. The conclusions from the previous chapter inform the approach chosen in this chapter for analyzing and explaining property-level land clearing trajectories by large-scale soybean producers. I open this chapter by three points motivating this fine-scale analysis.

First, since rural properties in the Amazon-Cerrado transition areas presented a variety of native vegetation cover type including forests labelled as transition areas, the clearing of these areas may have been more likely to be spotted by the PRODES (or DETER) and thus followed by policy enforcement. To be sure, this level of enforcement in the Cerrado biome was still lower than in the Amazon biome, but this does not mean that there was no intra-Cerrado biome variation in the enforcement of environmental policy. Yet the overall monitoring of clearing may still have been low given the priority of the federal government (focusing on the Amazon biome) and the sporadic nature of forest cover in the Cerrado biome.

Second, until recently we had limited knowledge about land clearing processes in the Cerrado biome because most of the policy attention was given to the Amazon biome while the Cerrado was being actively converted to soybean fields. In fact, Rudorff and Risso point out that 57% of the soybean production of the Cerrado biome is concentrated in two states, Mato Grosso and Goiás, each with 35% and 22% respectively in 2014 (Rudorff and Risso 2015). Although it is deceptively difficult to find accurate information on land-use change in the Cerrado prior to 2000, one may note that the trends in the replacement of native vegetation by soybean expansion post-2000 vary significantly across regions. For instance, Mato Grosso cleared 3,566.9 km^2 of native vegetation to expand soybean in the 2001-2006 period (28% of total expansion) and Goiás cleared 328.5 km^2 of native vegetation over the same period (3% of total expansion). In the following 2007-2014 period, these percentages had gone down to 5% and 2% respectively, demonstrating that most expansion occur over former pastures. In contrast, much of the expansion in the Cerrado areas of MATOPIBA occurred over native vegetation, with 5,159.3 km^2 in the 2001-2006 period and 9,137.5 km^2 over the 2007-2014 period, representing 45% of the total expansion for each period . (Rudorff and Risso 2015). MATOPIBA is therefore the area presenting the highest risks for native vegetation replacement by soybeans. (G. Oliveira and Hecht 2016; Morton et al. 2016; Carneiro and Costa 2016).

The lack of documentation for Cerrado deforestation patterns was also partly addressed previously at the state-level by a large body of work reviewing land-use change in Mato Grosso from the 2000s up to the mid 2010s (VanWey et al. 2013; Arvor et al. 2012, 2017; Spera et al. 2014; Macedo et al. 2012; Morton, DeFries, Shimabukuro, Anderson, Arai, Espirito-Santo, et al. 2006; Morton et al. 2016; Gollnow and Lakes 2014; Gibbs et al. 2015; R. D. Garrett et al. 2018).

Yet studies often presented have two limitations: (1) they rarely review deforestation patterns that occurred before the 2000s; (2) they interpret land clearing patterns based on a wide variety of soil, climate, price and institutional (i.e. governance) variables that range across different scales (e.g. local, state, regional, and macro), but more frequently at the macro-scale.

As a result, such studies rarely examine the micro-level of producers' decisions, which could provide a valuable avenue for understanding why land clearing has unfolded differently from one municipality to others (One notable exception is a study by Carauta et al. (2016)). As researchers have demonstrated, the hypothesis according to which cropland expansion occurs primarily on the highest suitable land has not been proven correct. Comparing different models examining the potentially available cropland (PAC) in Mato Grosso, Morton et al. (2016) found in fact that most cropland expansion between 2001 and 2012 expanded on low or moderately suitable areas. They conclude that models of PAC need to better delineate the differences between "necessary and sufficient" conditions for production and should pay "careful attention to technology, market, and policy changes that alter the underlying gradients of crop suitability and PAC" (Morton et al. 2016: 99). If soybean producers did not expand on the most suitable cropland, it suggests that much remains to be done to understand their decision-making and what shapes the profitability of farms.

Third, regional studies have recently pointed out changes in land-use trends between the Amazon and Cerrado biome, especially with respect to cropland expansion movements (Carneiro and Costa 2016). Before 2006, the share of cropland expansion in each biome was roughly equal. Both biomes (in Mato Grosso) experienced declining deforestation rates after 2006 but the total cropland expansion in the Amazon biome "was more than double the new expansion in the Cerrado in the

years following the Soya Moratorium (2006–2012), largely through expansion onto previously cleared land" (Morton et al. 2016: 96). What would have been expected after the signing of the Soybean Moratorium was a lower expansion of cropland in the Amazon biome as compared to the Cerrado (because the direct conversion of forests in the Amazon biome was theoretically forbidden). The fact that cropland expanded less in the Cerrado portion of Mato Grosso than the Amazon biome suggests that the economic calculus of soybean farmers in the Amazon biome may have been very different from those of the Cerrado biome because of differences in local characteristics. Hence, it is particularly pertinent to explore these dimensions.

In this chapter, the objective is to document and analyze the land clearing trajectories of 56 soybean producers who agreed to share their property boundary information. A total of 65 property polygons were registered and mapped as some landowners revealed information about several properties or considered their main property to be made up of several separate properties. I combine a land-use change analysis of these properties based on Landsat satellite images and combine them with the 104 farmers interview in order to reconstitute the land clearing patterns of the region and bring new evidence to the logic of land clearing in this frontier. The main research questions explored in this chapter are: (1) Do we observe changes in the rate and pace of land clearings over the period of analysis? (2) Can these changes be related to institutional (policy) changes or do they have more to do with economic conditions? The findings show that some assumptions made by the deforestation literature need to be nuanced as economic or institutional (e.g. policy) changes did not always result in opportunistic changes in land clearing behavior there. Rather, large-scale farmers in this region followed long-term plans grounded in the profitability perspective of their farms and fluctuations in economic conditions or policy changes seem to have

brought limited change to their plans at the farm-level. Farmers were driven by their vision and determination for occupying this region which would explain why they kept clearing native vegetation at a fairly high pace even in troubled economic times (especially the 1985-1995 period).

2. HYPOTHESES

I develop below a series of hypotheses which will support the analysis of the land clearing trajectories of large-scale soybean producers, building on the conclusions of all previous chapters. In chapter 2, for instance, I demonstrated the techno-cultural identity common to colonizers as well as the similarity in colonization plans. Despite sharing some characteristics (common origin, agricultural technology, etc.) this group also presents differences (property size, year of arrival, environmental values, funding, etc.). Since soybean producers all differ from each other based on their individual characteristics, their history, their socio-economic status, or their environmental values, one may expect that they react differently to changes in economic factors along time. For instance, even if production systems in the study area are very similar since they are based on double cropping systems, there may be considerable variation in the yields obtained by each producer, since each one makes choices representing a unique combination of an increasing number of production variables (Carauta et al. 2016). The semi-structured interviews conducted for this study also confirms the high heterogeneity in production decisions (See chapters 5 and 6). Producers often highlighted how their land clearing and land consolidation strategies differed from one another.

These observations led to the formulation of a first hypothesis that support the point that soybean producers form a group presenting some heterogeneity in land-use decisions because of their

heterogeneous background. I expect most soybean producers in the sample to differ in the pace and timing of property clearing:

H1: Producers have different pace and timing of property clearing

The three observations made about land clearing patterns in the Amazon-Cerrado transition region in the introduction to this chapter form the basis of the second and third hypotheses. These hypotheses build also on the main points of chapters 1 & 2, which was to demonstrate that the colonization of Amazon-Cerrado transition areas occurred in a very specific context different from colonization in the Amazon areas. The smallholder farmers arriving from Southern Brazil into Cerrado areas of Mato Grosso shared a common cultural background and embraced similar agricultural technologies centered around rice and then soybean production. Those who went to Amazon areas had a different plan and went for a variety of land-uses but relied dominantly on cattle-ranching, an aspect clearly discernable among the municipalities included in the sample with the example of Sinop. As a consequence of sharing similar agricultural projects, one may expect properties in the Cerrado biome to follow a common trend in timing and pace of clearing while those in the Amazon should follow a clearing pattern that differ in time and pace while presenting some similarity to that of the Cerrado, since they started producing soybean too:

H2: Landowners in Cerrado-located properties follow a similar progressive and constant clearing pattern and differ from those in Amazon-located properties

In addition to the difference in historical land-use trajectories across municipalities located in different biomes, it is important to stress that the differences in land-uses and location should imply that landowners responded differently to changes in economic conditions or governance conditions (i.e. environmental policies). Theoretically speaking, if farmers were only reacting to institutional and economic factors, land clearing rates would vary accordingly across time and evolve in similar ways across the board. On the contrary, if the clearing of a property is part of farmers' long-term project to produce crops and occupy the area, then one should observe a resolute pace of clearing that is only marginally influenced by economic fluctuations or policy changes. In addition, I demonstrated in Chapter 3 the variability in environmental policy enforcement and the relative "lack of attention" paid to farmers in the Amazon-Cerrado transition areas. Since I argued that environmental policy monitoring and enforcement was weaker in the Cerrado areas (although, even weak, it presented theoretically some variation due to the presence of some forest cover), I would expect properties in such biome to be less subject to external pressures such as changing economic and policy changes.

H3: Landowners' decisions about land clearing in Cerrado areas were limitedly influenced by changes in economic conditions or environmental policies while those in Amazon areas were more affected by such changes.

3. DATA & METHODOLOGY

The objective of this analysis was to examine land-use change on the surveyed properties over a period stretching from 1985 to 2015. These time boundaries correspond approximately to the initial date at which most interviewees arrived in the region (producers born before 1980 arrived

in 1984 for an average[208]) and the date of the study (which was 2 years later than 2015), thus covering the period where the majority of clearing occurred. Relying on a visual classification, the use of which I justify below, the land-use data was generated by periods of 5 years for the entire period of study to both allow for the detection of significant amounts of clearing and reduce the data treatment burden.

3.1. DATA

3.1.1. Property grid

The property boundaries used in this study were reported by the interviewees themselves. At the end of each interview, I asked the interviewees whether they would accept to draw the boundaries of the farm used as a reference for the interview. Since some landowners may own or rent several properties, the "property of reference" was the landowner's property that would meet all or most of the following conditions, ranked in order of importance: (1) first (or oldest) property acquired in the area; (2) largest property owned (and not rented); (3) property located in the municipality where the landowner resides. The rationale for such criteria was to get data on the property which represented the longest history of land-use the landowner was responsible for, in order to match as well as possible land-use history with interview data.

Large paper maps representing Landsat TM and ETM+[209] satellite images of the municipality in 2010 (Global Land Survey) were used. The coloring (using a RGB coloration combining Landsat TM bands 5,4,3) allowed for a quick identification of native vegetation and agricultural areas to ease farmers' perceptions of their own farm. Farmers drew property boundaries over tracing paper

[208] This number represents 79 individuals. The sample average arrival date was 1986 (n=104). This second average includes sons of landowners.

[209] Enhanced Thematic Mapper Plus (ETM+) was a sensor aboard the Landsat 7 satellite

to ensure no marks would be left on the map and each successive interviewee would be guaranteed complete anonymity. In some cases, farmers would prefer to provide me with the official documentation about their property, either under the form of official cadaster documents from the local notary office (called "georeferenciamento") or the Environmental Rural Cadaster (CAR).

All this data was transformed into KML polygons using GoogleEarthPro 7.3.1.4507 (64-bit) for MacOS. The process of drawing property polygons in GoogleEarthPro based on maps that were drawn by hand by the farmers can naturally generate errors. On the most recent satellite images available at the time of drawing (September-November 2017), it is still very difficult to locate the exact path followed by rivers and other headwaters. This could somewhat be a concern because these waters are in almost all cases the "natural" boundaries of these properties. However, this measurement "error" remains non-significant when considering the large size of properties. I therefore did my best to draw the property lines following the course of the river when they were available. When not available, I would follow either the center of the denser forest area splitting two distinct agricultural fields (i.e. two different properties). In a few instances, when not able to discern any presence of a river under the tree cover for small lengths, I simply took the center of the forest area as a reference. KML polygons were subsequently transformed into layers and polygon features into ArcMap 10.5 for analysis. Polygons were projected using the "GCS_WGS_1984_UTM_Zone 21N" projection to minimize distortions within the Zone 21 which encompasses Mato Grosso. It also ensures coherence with the projection of satellite images used in this study.

A total of 65 property boundaries were registered. They belonged to 56 different landowner families[210] (including 7 operational managers linked to the management of a family's land) and represented the operations of 66 individuals interviewed in the sample. Thus, the property data represent land-use decisions for about 63% of the sample (66 individuals over 104 interviewees). Although interviewees were asked to release information only about their main property (serving as a reference for the questionnaire), 6 landowners families decided to release information about more than one property boundary. They did so either because their property was scattered into several pieces, or because their main property is the result of the acquisition of several different pieces over the years. Importantly, since there were some landowners with one property boundary and others with several ones, the land clearing data was summarized by landowners (and not by property) to ease the interpretation of the actions of each respective landowner. This means that, for these 6 landowner families, a small percentage of the clearing data may come from properties acquired later than the first georeferenced property and may have even been deforested by previous owners (e.g. one property acquired in 2002 to various landowners for 20-30 years who did the clearing. Overall, the average property acquisition date in the sample was 1986 and the median year was 1985, which ideally fits the start of the study period.

These minor caveats are not significant considering that the analysis focuses more on the deforestation decisions of landowners through time than the lifecycle of a given property (granted that in 51 out of 57 cases, both are confounded since each landowner family declared only one property). I therefore included all properties to get the richest information possible, keeping in

[210] Here one "family" can represent one or more individuals

mind that for the overwhelming majority of properties, the landowner family can be considered to be the one responsible for the clearing for the study period (1985-2015).

3.1.2. Satellite images selection window & acquisition

Two requirements guided the choice of satellite images: (1) the set of images should correspond with dates allowing for the most accurate distinction between the different land-use classes; (2) the set of images should allow for land cover classification that minimizes the error at the property-level. To analyze land-cover change, I conducted optical remote sensing (OLS) on Landsat Thematic Mapper (TM) images (Landsat 5 and 8 satellites) (Brondizio and Van Holt 2014). However, before making a choice about which bands to combine into an image that accurately represents vegetation change, it was necessary to choose the date range within which images are most likely to maximize the observation of vegetation cover change. An additional challenge was to find a period that can serve to analyze both the Cerrado biome and the fraction of the Amazon biome included in the study. During the rainy season, observation of land-use is generally made difficult because of important cloud cover (E. E. Sano et al. 2007). Additionally, the distinction between cropland (i.e. soybean or corn growing), pastures, native grasslands can be tricky because most land-use classes represent green biomass that look alike in the rainy season (Risso et al. 2012). After a review of the literature and fieldwork observations, it appears that the most appropriate time window for satellite image selection is the May-September period, during the dry season (B. F. T. Rudorff, Adami, Aguiar, Moreira, Mello, Fabiani, Amaral, and Pires 2011; Epiphanio et al. 2010; E. E. Sano et al. 2007; Risso et al. 2012; Durigan 2012; Carlos and Ricardo 2005; Jepson 2005; Welch et al. 2013; Arvor et al. 2011). This window is appropriate for both the Cerrado and Amazon biomes.

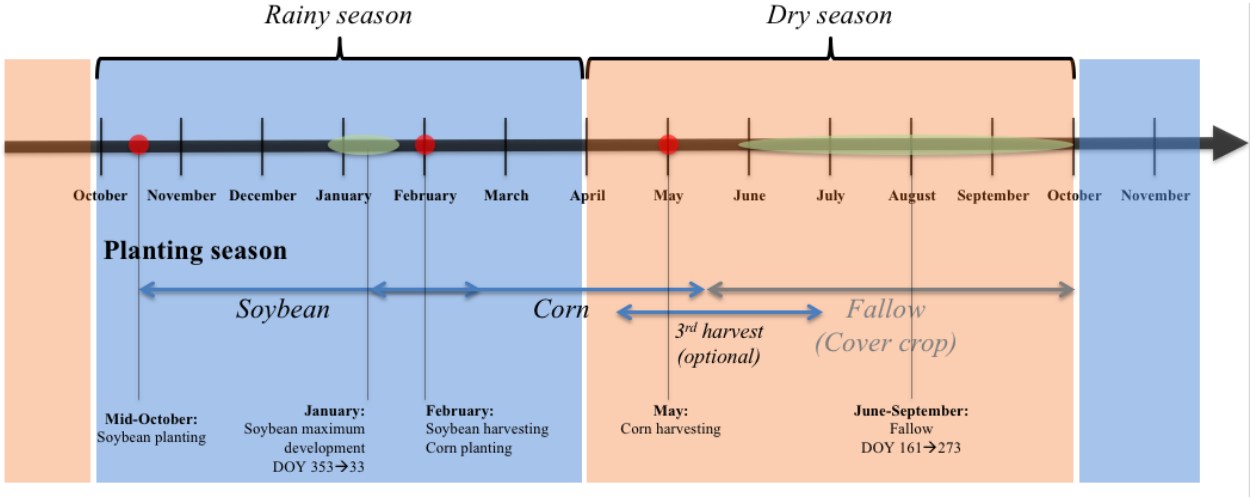


Figure 4.1. Illustration of the main climatic seasons and crop plantation calendar in the Cerrado study area used to guide the optimal period of satellite image selection.

Second, it is necessary to determine which period allows for the greatest accuracy in land-use classification. Remote sensing studies relying on unsupervised or supervised classification[211] to detect soybean cultivation tend to rely on the satellite images taken during the dry season and fallow periods using the MODIS (Moderate Resolution Imaging Spectroradiometer) sensor. At this period, the Normalized Difference Vegetation Index (NDVI) is more able to show differences between soybean and sugarcane, pastures, Cerrado, and forests. The ideal window is between Day-Of-the-Year (DOY) 161 to 273. The problem during the rainy season (and best soybean growing season, but cloudy season) is that the peak response of soybean is very short, and areas will react differently depending on the planting date.[212] Other land classes (e.g. native vegetation) also reach high vegetation indices at the same moment. As a result, the NDVI is not adapted for distinguishing

[211] A supervised classification (i.e. classification by computer) is performed by a software that identifies groups of pixels based on the similarity of their spectral features in the image. The classification is made automatically based on this criterion and the user can only specify how many land classes should be produced. On the contrary, in an unsupervised classification (i.e. classification not by computer), the user selects which pixels should the computer compare its classification against. In other words, the users "supervise" the classification by specifying classes of different spectral strength which the computer uses for classification. This choice is usually based on the user's expertise and often complemented by fieldwork to compare classification results in certain georeferenced points with on-the-ground land cover.

[212] In this area, farmers may plant soybeans at different dates based on differences in rainfall patterns or difference in the nature of the crop planted in second harvest (corn or cotton).

classes during the rainy season. Researchers can however rely on the Enhanced Vegetation Index (EVI) which is more sensitive to the variation in green biomass, especially in humid areas (Arvor 2009). In Mato Grosso, the EVI is better at distinguishing between land classes between DOY 353 to 33 (Risso et al. 2012). Some authors have been able to map soybean areas using EVI with a total accuracy of over 91% (Rizzi et al. 2009). Arvor et al. (2012) were able to classify areas under double cropping with an accuracy of 95% for soybean followed by corn and 86% for soybean followed by cotton. Another classification of vegetation cover in the Cerrado had an accuracy of 91% for agricultural areas, 86% for Cerrado areas and 84% for forests (Welch et al. 2013). Jepson's (2005) unsupervised classification of land-use change in the Cerrado demonstrates a classification accuracy based on ground truth data of 94.75%, with 95.34% for Cerrado areas and 97.56% for agricultural areas.[213]

A MODIS-based supervised or unsupervised classification was not chosen for the analysis, however, since they are too advanced (i.e. for distinguishing among land cover types) and not enough precise for the scale of property-level analysis needed here. Since the objective of the classification is simply to segregate human use (i.e. cropland, pastures) from natural land covers (i.e. forests or savanna vegetation) for 65 different property polygons over 30 years, the choice was made to rely on Landsat TM images. Despite the fact that optical remote sensing takes more time than a supervised or unsupervised classification, the increased quality in area measurement was worth the time investment. MODIS image resolution is of 250 meters which result in a pixel of 62,500 square meters (m^2) (6.25 ha), to be compared against property areas ranging from 500 ha to 10,000 ha or more. In contrast, Landsat images have a 30 meters resolution which allow the

[213] **Note**: there area only 21 pixels of forest in Jepson's analysis, making it impossible to conclude as to the accuracy of the forest classification.

identification of pixels of 900 m^2 (0.09 ha). A second issue would have been to check for the consistency of a MODIS-based classification across the 30-years analysis period. Unsupervised classifications sometimes control for accuracy by examining land cover on the ground at certain points of the classified image. This is not possible in the present case since the duration of analysis (1985-2015) would require getting aerial photos of the land cover in the 1980s and 1990s, which may not be available or difficultly accessible over for the geographical extent of the study;

As a result, the total error in classification accuracy that would have resulted from another method than using Landsat TM may have been too high for the purpose of the present classification. The classification error of the above-mentioned studies range from 5% to 15%, an error range which may significantly influence my interpretation of whether a property complies with the Forest Code (FC) or not. Relying on such type of classification for a property-level analysis would not be satisfying since it would be incorrect 5 to 15 percent of the time. Furthermore, the multi-temporal nature of this study (looking at change throughout several periods) would lead to land change images with an even greater inaccuracy since "errors compound multiplicatively with data integration: Two land cover maps, with 90% overall classification accuracy, when overlaid for change detection will yield a transition image whose accuracy may not exceed 81% overall" (Brondizio and Van Holt 2014: 621).

I therefore used Landsat 5 and Landsat 8 TM images with 30-meters resolution. Satellite images were acquired from the United States Geological Survey (USGS) Earth Explorer database. Landsat 5 TM images were used for the 1985-2010 period (to insure consistency across 5-year periods)

while Landsat 8 OLI/TIRS[214] images were used for 2015. Scenes for the Alto Teles Pires region (225/68, 225/69, 226/68, 226/69, 226/70, 227/68, 227/69, 227/70, 228/68) and the Chapada do Parecis region (227/69, 227/70, 228/68, 228/69, 228/79, 229/68, 229/69, 228/70) presented 0% cloud cover over the studied area of the properties (minor cloud area can occur on some images, but never over the actual study area). Only exception, the 1984 year was preferred to the 1985 for the Chapada do Parecis region because of data unavailability and important cloud cover. All USGS Landsat images are orthorectified which minimizes distortion due to variations in the topography of the terrain.[215] Image features such as roads and rivers prove to be consistently aligned between each image date.

3.1.3. Semi-structured interviews

A set of 104 semi-structured interviews was used to (1) understand the land-use change and land clearing processes of the study period (2) match the land clearing behavior to interviewees' statements for the 57 landowner families covered by the land-use change analysis (66 individuals with whom interviewed were conducted). These interviews contain important information about the context of arrival of these landowners, their settlement history and land-use decisions. Interviewees very often described the pace of land clearing, the type of vegetation they would clear, and the rationale for doing so. In addition, the interview data includes information about how they perceive the impact of various public and environmental policies was on the behavior of landowners in their municipality in the past and today. These measurements were done following a 5-point Likert-scale describing whether they thought policies had no effect at all (1) to whether they had fundamentally deterred landowners from clearing more native vegetation (5).

[214] OLI stands for Operational Land Imager and TIRS means Thermal Infrared Sensor.
[215] This is however a minor concern in this case because the analysis concern areas with little variation in altitude

3.2. METHODS OF ANALYSIS AND LAND-USE CLASSIFICATION

3.2.1. Band combination to identify vegetation features

Vegetation cover is best captured by spectral resolutions ranging from near infrared to mid-infrared, which is not visible to humans. It is however to use the spectral reflectance values of the landscape feature recorded in these bands to compose a regular image combining red (R), green (G), blue (B) coloring. By doing so, one can create images that emphasize (with artificial coloring) the different vegetation features of the landscape. The reflectance of vegetation is maximal in the red to near-infrared wavelength region while it tends to drop and hit a bottom in the mid-infrared region. As a result, an image combining these bands will likely maximize the variability in green biomass reflectance (between the peak value and lowest value) and help distinguish between different land covers (Arvor 2009).

To create an image that most accurately distinguishes vegetation cover from agricultural cover for the analysis, I chose to color images based on a R-G-B combination of bands 5-4-3 from Landsat 4-5 TM. This most common vegetation analysis band combination relies on "MidInfrared" (band 5) for Red, "NearInfrared_1" (band 4) for Green, and "Blue" (band 3) for Blue (**See Table 4.1**). Band 5 helps separating water bodies from forests and cropland since it is sensitive to moisture content. In this context, forests and water have a higher reflectance than cropland. Since water absorbs most infrared, band 4 is useful to distinguish between vegetation types. It separates well degrees of dryness in soils, from bare soils to crop land. Band 3 is the chlorophyll absorption band and makes vegetation appear in darker since it absorbs all red light. It helps distinguishing vegetation from bare soils (Horning 2004).

Using such image coloration ensures that forests will appear in vivid green, crop land in light pink and bare soils in pink/purple. Landsat 8 OLI-TIRS images are slightly different since they record 11 bands. The corresponding band combination using Landsat 8 is thus 6-5-4. Past studies have combined similar bands. For instance, Jepson (2005) uses this combination of Landsat TM bands for an unsupervised classification of land-use change in the Cerrado (focusing on the municipality of Canarana, Mato Grosso).

Image band combination	Band designation	Micrometers range (µm)	Landsat 4-5 TM	Landsat 8 OLI-TIRS
RED (R)	Shortwave Infrared (SWIR)	1.55-1.75	Band 5	Band 6
GREEN (G)	Near Infrared (NIR)	0.76-0.90	Band 4	Band 5
BLUE (B)	Red	0.63-0.69	Band 3	Band 4

Table 4.1. Combination of Landsat TM and OLI-TIRS band used for coloring images for visual identification of land cover.

The overall goal of the classification is (1) to separate native vegetation from anthropized areas (agricultural fields, fires, roads, on-property constructions like farm houses) and (2) distinguish between forest formations and Cerrado grasslands. Given the great diversity of vegetation categories in the Cerrado (see Introduction), this latter distinction is necessarily approximate. In the study area located in the Cerrado biome, denser forests are often located next to rivers (corresponding to forest formations of the Cerrado, named *cerradão*). This class poses difficulty to both supervised (Welch et al. 2013) and unsupervised classifications (Jepson 2005) since the spectral signature is very close to forest formations of the Amazon biome. The gradient and progressiveness of vegetation in Cerrado areas is thus the main source of uncertainty in land cover classifications.

3.2.2. Definition of land classes

Four different land categories are identified based on the images generated by the band combination:

1. **"Forest"**: This land-use class regroups forest formations typical of the Amazon biome (dense ombrophile forests), and Cerrado biome formations such as semi-deciduous forests (like *cerradão*) which tend to have a high reflectance in the near infrared region (band 4) which is used to as the green color in the band combination. These land-cover form continuous shapes of dark or vivid green color (e.g. typically along watercourses) or form clearly identifiable small patches.
2. **"Herbaceous/Woody"**: This land-use class correspond to areas that do not quite qualify as forest under the category 1, and which classification into a savanna vegetation (i.e. Cerrado) type is uncertain. These areas are clearly distinct from forests but appear in vivid green on the image. They are usually located near forests but present geometric shapes (e.g. squares or triangles) right next to forest cover, which suggest that they were cleared or subject to human-use in the recent past. These areas could possibly represent grown pastures or areas under natural regeneration. Importantly, these areas were mostly identified in the Amazon biome in the early years of analysis (e.g. 1985-1990) and they represent less than 1% of the total area classified in the study per year.[216]
3. **"Cerrado":** The land-use class defined here as "Cerrado" represent areas mostly occupied by grassland, shrubs, or small trees. It therefore excludes Cerrado forest

[216] The area classified as herbaceous/woody corresponded to 0.5% of the land-use classified in 1985 (1,755 ha out of 324,581 ha). In 1985, these areas were located in 5 properties in Sinop (dominated by ranching at the time, which supports the hypothesis that these may be grown pastures or recently cleared land on the way to regrow) and 2 properties in Nova Mutum (one of which only relied on cattle-ranching at the time; ITW n°006).

formations since they are accounted for in the “Forest” category. These areas typically appear either in light green or brown "haze", or brown and beige tones on the image.

4. **“Agriculture”**[217]: All areas under this category are not identified as native vegetation in any of the first 3 categories. These corresponds to areas cleared in previous years such for agricultural fields, by human-induced fires, or road and urban infrastructure. Agricultural areas appear in light to medium pink and clearly have geometric shapes (lines, 90° angles, squares, triangles). Fires or burnt Cerrado areas appear in dark pink and usually have non-geometric shapes. Fires also occur naturally in the Cerrado (Welch et al. 2013). I identified at times large natural Cerrado fires spanning over an area several times larger than an actual property. In order to determine whether fire was natural or human-induced, I compared the current image to the next one five years later. If any agricultural activity was taking place over the area, I would conclude that the fire was human-induced, if not I concluded it was natural and classified the area as Cerrado (Category 3).

[217] I refer to agriculture as a land class here instead of referring to “anthropized area.” The reason is that all land occupation in the area was related to agricultural activity and construction and road features within a large-scale properties represent a very negligible area. Hence, I assimilate every human-induced transformation to be agricultural in nature or in the purpose.

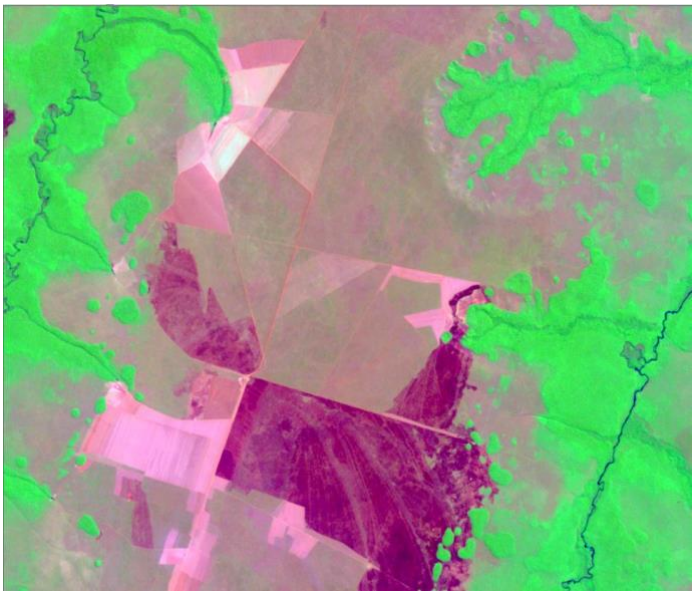
Example: Landsat 5 (TM) Image of 1985	**Criteria for land classification**	**Land cover classification**
	Continuous, light and dark green; small isolated green spots detached from a main body; non-geometric (no line)	1° Forest
	Vivid green, geometric form, seemingly detached from main vegetation bodies	2° Herbaceous/ Woody
	Light greenish-brownish "haze"; brown/beige areas	3° Cerrado
	Light pink to dark purple, clearly delineated in geometric form (lines, 90° angles, squares, triangles) Or non-geometric (fires)	4° Agriculture (or recent fire)

Figure 4.2. Description of land categories used for the study with a sample Landsat 5 (TM) image from 1985.

Land-use class polygons were drawn into ArcMap 10.5 using a constant resolution of 1:40000 (1 centimeter =40000 centimeters = 4 kilometers) and the default projection of satellite images (GCS_WGS_1984_UTM_Zone 21N). Working on a property-per-property basis, I classified in forests, herbaceous/woody, and Cerrado (all vegetation) polygons within each property for each 5-year period. After completing this task for every observed year, I generated the agricultural land-use polygons by subtracting the vegetation polygons to the property polygon area (i.e. all that does not correspond to native vegetation in a property is therefore considered as anthropized). Finally, I combined all polygons into a single shapefile for each year.

3.2.3. Robustness of classification

In order to get some sense of the accuracy of the optical remote sensing method, I compared the results of my land cover classification for agricultural areas (i.e. total area cleared on a property) to official deforestation datasets for the Amazon and the Cerrado biomes. This land-use classification was compared against:

1. The PRODES dataset maintained by the National Institute for Space Research (INPE) and documenting deforestation from 1988 (estimates before 1988 are unreliable) (Philip M. Fearnside 2005b; INPE 2018a). The dataset available to the public contains deforestation polygons for 1997 (deforestation accumulated until then) and then every year from 2000 to 2015. The comparison with this dataset includes all properties in the sample.
2. The deforestation dataset for the Cerrado biome made available by the Brazilian Environment Ministry. The dataset available to the public contains land clearing polygons every two years from 2000 (the 2000 polygons record all mapped areas of cleared native vegetation before that date) until 2012, and then provide yearly estimates for the remaining years from 2013 until 2017 (INPE 2018b). The comparison with this dataset only includes the property located in the Cerrado biome (because there is no data for the Amazon biome).

Since the deforestation dataset covering the Cerrado only contains dates starting in 2000 and every 2 years until 2012 (it provides yearly data after), I was only able to compare estimates generated by the study starting from that date. Furthermore, it does not contain much refinement in the land classes, merely distinguishing between human-modified areas, deforestation/land

clearing polygons, and forests/native vegetation areas. Therefore, I compared the total cleared area per property from my dataset (category: agriculture) to the total area cleared from these datasets according to this formula:

$$\%classification\_error = \%cleared\ (study\ dataset) - \%cleared(Cerrado\ or\ PRODES)$$

Average percentage error in land-use classification	**PRODES Cerrado dataset** Compare only Cerrado areas				**PRODES dataset** Compare both Amazon and Cerrado areas (albeit imprecisely in the Cerrado)			
Period	**2000**	**2005**	**2010**	**2015**	**2000**	**2005**	**2010**	**2015**
CERRADO biome	-0.69%	-0.36%	-0.28%	-0.42%	-15.07%	-11.32%	-11.22%	-11.53%
AMAZON biome	-	-	-	-	-5.02%	-3.79%	-3.70%	4.73%

Table 4.2. Robustness test for land-use classification using two official land clearing datasets: Cerrado Desmatamento (MMA) and PRODES (INPE).

The results from the robustness check indicate that the visual interpretation of the data is roughly equivalent to the official Cerrado land clearing dataset. This indicates that the area identification can be trusted at least from 2000 on, and consequently indicates that the overall land classification process was of good quality. With respect to the PRODES dataset, the results indicate that official estimates tend to overestimate land clearing from about 11.2% to 15.1% for areas located in the Cerrado biome, and from 3.7% to 5% in the Amazon biome. The results are not so surprising for the Cerrado areas because the PRODES system does not identify well drier forest cover typical of savanna areas. According to Richards et al.: "PRODES has never monitored dry or secondary forests in the Amazon Biome (…)" (Richards et al. 2017). The results for the Amazon biome, although different than mine, present fairly close estimates to mine. This means that the PRODES system identify fairly well deforestation of humid forests at the property-level within the Amazon biome.

3.3. LAND-USE CHANGE ANALYSIS

In order to determine the extent of native vegetation land clearing for each time period, I conducted a transition matrix analysis using Erdas Imagine 2014. By comparing the pixels from one year to the other, transition matrix allows whether pixels have changed or remained identical, thus providing with information about the land-use change occurring between each period. For instance, if a pixel classified as forest in the first image becomes a pixel classified as agriculture under the second, this will indicate that deforestation has occurred in between the two periods. Transition matrices were generated for the following periods 1985-1990, 1990-1995, 1995-2000, 2000-2005, 2005-2010, 2010-2015.

The purpose of this analysis is not only to understand the land-use change dynamics for the sample during the study period, but also to identify what type of vegetation was wiped out with land clearing. Far too often, studies in the Legal Amazon consider land clearing in the *Cerrado* biome as "deforestation" of forests, statistically equating deforestation in the Cerrado to deforestation in the Amazon (e.g. Azevedo 2009). This poses a conceptual problem since native vegetation in the Cerrado is incredibly diverse and does not have the same biophysical characteristics than in vegetation in the Amazon, let alone the same carbon storage properties (Jepson 2005). If we take into account the carbon contained in the vegetation land cover and the soils, forests of the Amazon biome hold 280-450 Mg of CO2 per hectare while savannas from the Cerrado biome hold 97-170 Mg of CO2 per hectare (PBMC 2013). Whether native vegetation can be considered equivalent within the Amazon biome is also debatable (Le Tourneau 2016). This distinction has important implications for studies aiming at evaluating greenhouse gases emissions from deforestation.

Given that the land-use classification is based on 4 categories, there are 16 combinations of land cover transition: 4 identical changes and 12 category changes. To ease interpretation, the 12 possible land cover changes are classified in two categories: 1) more vegetation and 2) less vegetation. Below is the interpretation table for land classes change between two periods.

1985 image		1990 image	Land-use class changes	Interpretation
1. IDENTICAL LAND COVER				
Forest	→	Forest	**forest**	Forest preserved throughout the time period
Herbaceous/ Woody	→	Herbaceous/ Woody	**herbaceous/woody**	Herbaceous/woody area under regrowth, cultivated pastures, or classification error
Cerrado	→	Cerrado	**Cerrado**	Cerrado transitioning to Cerrado, presenting no land-cover change
Agriculture	→	Agriculture	**agriculture**	Agricultural areas maintained throughout the period
2. LAND COVER CHANGE				
2a. More vegetation				
Cerrado	→	Forest	**regrowth**	Cerrado growing into denser forests.
Cerrado	→	Herbaceous/ Woody	**regrowth**	Cerrado growing into a light-green uniform patch, indicative of forest regrowth or pasture cultivation (or classification error)
Herbaceous/ Woody	→	Forest	**regrowth**	Forest regrowth now re-integrated to neighboring forest patches intact at the beginning of the study
Forest	→	Herbaceous/ Woody	**regrowth**	Indicative of recent clearing not followed by anthropic uses. As a result, regrowth in this area occurs in following years (or classification error)
Agriculture	→	Cerrado	**regrowth**	Regrowth of Cerrado vegetation after anthropic uses. Note: if classified as such, they are counted as "native" Cerrado cover in the next time period
Agriculture	→	Forest	**regrowth**	Regrowth of forest type vegetation after anthropic use
Agriculture	→	Herbaceous/ Woody	**regrowth**	Regrowth of vegetation or cultivation of pastures (or classification error)
Herbaceous/ Woody	→	Cerrado	**Cerrado**	Vegetation regrowth into Cerrado vegetation
Forest	→	Cerrado	**Cerrado**	Natural forest degradation or classification error
2b. Less vegetation				
Forest	→	Agriculture	**deforestationF**	Forest cleared for agriculture or other anthropic uses
Herbaceous/ Woody	→	Agriculture	**deforestationF**	Clearing of herbaceous/woody areas for agriculture or other anthropic uses
Cerrado	→	Agriculture	**deforestationC**	Cerrado cleared for agriculture or other anthropic uses

Table 4.3. Land-use class changes from one period to the other (here 1985 and 1990) and corresponding land-use change interpretation of pixels category change.

		2015 Image (ha)				
	Land class	*Forest (31%)*	*Herb. (0.2%)*	*Cerrado (2.1%)*	*Agriculture (66.6%)*	TOTAL (1985)
1985 Image (ha)	*Forest (54.3%)*	99,661.2 ha (56.5%)	380 ha (0.2%)	134.5 ha (0.0%)	76,179.1 ha (43.2%)	**176,355 ha**
	Herb. (0.5%)	57.2 ha (3.2%)	120.7 ha (6.8%)	0 ha (0.0%)	1,577.4 ha (89.8%)	**1,755 ha**
	Cerrado (28.1%)	341.8 ha (0.4%)	115.4 ha (0.1%)	6,598 ha (7.2%)	84,289.8 ha (92.3%)	**91,282 ha**
	Agriculture (17%)	488.5 ha (0.9%)	170.5 ha (0.3%)	266.7 ha (0.5%)	54,208.7 ha (98.3%)	**55,134 ha**
	TOTAL (2015)	**100,548 ha**	**786 ha**	**6,999 ha**	**216,246 ha**	**324,581 ha**

Table 4.4. Land use change (per hectare and percentages) between 1985 and 2015 on the surveyed properties. **Explanation**: The (rounded) percentages in the boxes correspond to the distribution of 1985 land cover (leftmost row) among the 2015 land cover categories. Categories that did not change (identity categories) are highlighted in dark green, while categories who corresponds to more vegetation are in light green and those with less vegetation are in light red. **Reading**: (First row of land-use change data) "56.5% of forests present in 1985 have remained intact throughout the 1985-2015 period.

The land cover change matrix in **Table 4.4** details the extent to which the 4 different land classes have remained identical and the proportion of change from 1985 to 2015. The analysis shows that agricultural areas are the only land cover to have remained consistent (i.e stable) over this period. Quite obviously in a context of agricultural expansion, almost all (98.3%) agricultural area in 1985 have remained under this category. The percentage is not 100% however because some areas were burnt by farmers to clear native vegetation but have ultimately not been used for agriculture, leaving room for regeneration. On the contrary, most other land covers underwent change. 56.5% of forest formations existing in 1985 have remained, demonstrating that an important amount of initial forest cover has been preserved on private rural properties in general (99,621 ha as compared to 176,355 ha originally). It is a fairly important result since forest formations represented originally 54.3% of the total property area in the sample (they fell down to 30.9% in 2015). Because they are easy to clear, 92.7% (84,289 ha) of the Cerrado areas present in 1985 were

cleared. This land cover class passed from 28.1% to 2.1% of the total area over the analysis period. Finally, very few herbaceous/woody areas remained by the end of the period (6.8%). They represented a non-significant area for the analysis, passing from 0.5% to 0.1% of the total land cover over the period of analysis.

Table 4.4 helps identify meaningful land cover changes and to refine the interpretation of land cover changes. First, very few instances of regrowth hypothesized in the interpretation table above were proven possible after the transition analysis. Apart from herbaceous/woody areas turning into forests (3.2%) or agricultural areas turning back to forests (0.9%) over the 1985-2015 period, all other potential regrowth transitions neared 0%. Hence, in the discussion of the results, the *regrowth* class should be interpreted as the return of forest cover on a given area. Regrowth processes are fairly insignificant at the property level: herbaceous/woody areas represented 0.5% of the area covered by properties in 1985 and only 3.2% of this cover turned back into forests at the end of the analysis period. Only in the 1985-1990 did regrowth represent 1.1% of the total area change, supporting the idea that excess land may have been cleared at first and did not find immediate agricultural use in the following period, leaving time for vegetation to recover. Second, the results help classify two types of deforestation. The change from Cerrado areas to agriculture is classified as *Cerrado deforestation* ("DeforestationC"). 43.2% of existing forests areas disappeared because of agriculture, I therefore define this category as *forest deforestation* ("DeforestationF). Although an important part of land clearing concerned Cerrado areas, I nonetheless keep using "deforestation" to designate land clearing in both Cerrado and forest, simply indicating by a "C" or "F" whether land clearing concerned Cerrado or forest vegetation types respectively. Finally, it is important to note that these two categories of deforestation should not be conflated with

deforestation “in the Amazon biome” and deforestation “in the Cerrado biome.” Here, the deforestation of forest-type vegetation (DeforestationF) can occur in both biomes.

New land classes	Interpretation
DeforestationF	Refers to land clearing of “forest” (Category 1) or “herbaceous/woody” areas (Category 2) for agriculture
DeforestationC	Refers to land clearing of “Cerrado” areas (grassland, shrubs, small trees) (Category 3) for agriculture
Regrowth	Corresponds to areas formerly classified as “agriculture” (Category 4) or “herbaceous/woody” (Category 2) which turned back into “forests” (Category 1) over time.

Table 4.5. Re-coding of land-use change classes

4. RESULTS

4.1. THE CONSOLIDATION OF THE AMAZON-CERRADO TRANSITION AREAS INFLUENCED BY REGIONAL DIFFERENCES IN VEGETATION COVER TYPES (LAND-COVER CHANGE AT THE OVERALL SAMPLE LEVEL)

4.1.1. A steady pace of clearing until 2005

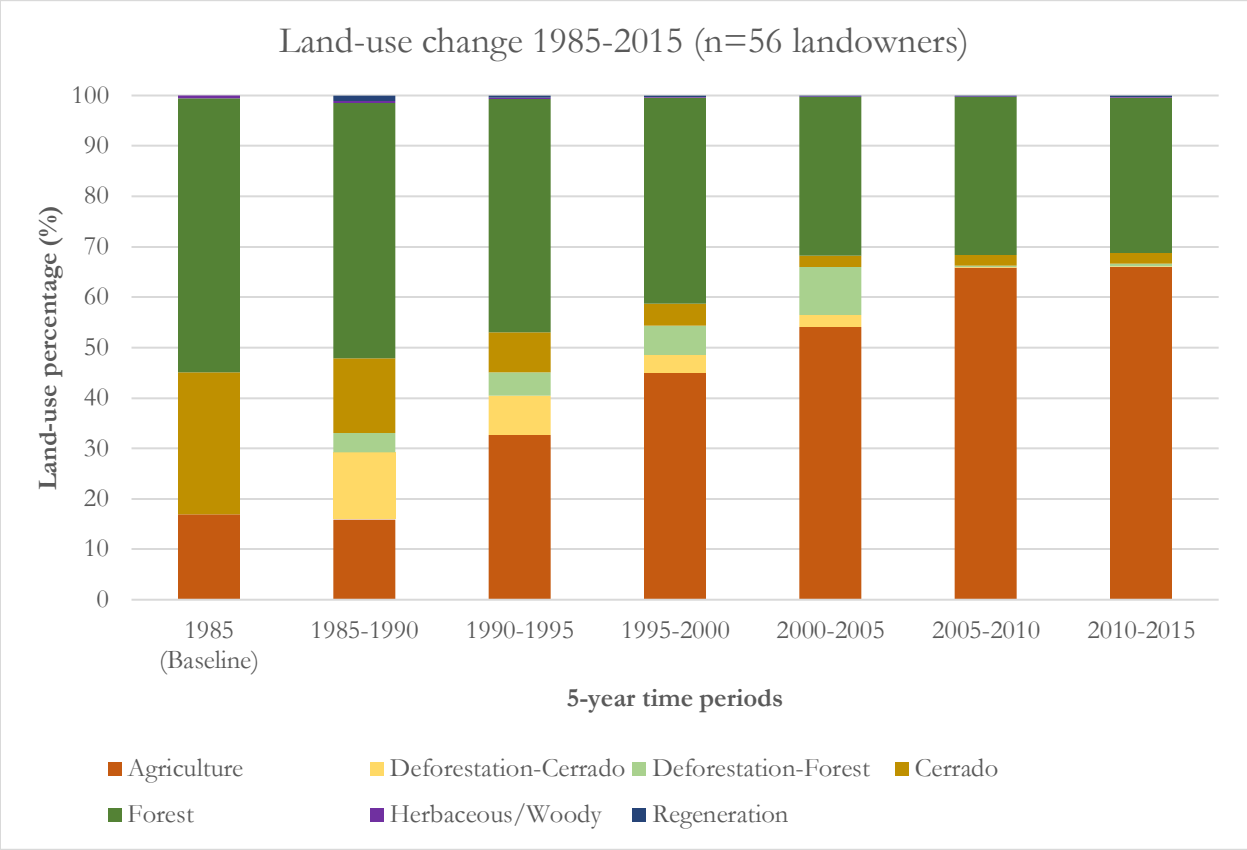


Figure 4.3. Land-use change in terms of area percentage of the surveyed properties (N= 65) for the landowners in the sample (N=56) in both the Cerrado and Amazon biome. The agricultural area passes from 15.9% to 66% of the total property area, on average across the sample. Total land area covered by the sample: 324,692 hectares[218] (ha). The small reduction in agricultural area between 1985 (1.1%) and the 1985-1990 land use data is due to areas classified in 1985 as agriculture because of fire use, but which regrew by 1990 (regrowth in 1990 is 1.1%).

In 1985, forest formations accounted for 54.3% of the total area occupied by the rural properties of the 55 sampled landowners (324,692 ha in total) (**See Figure 4.3**). The second dominant land cover were Cerrado areas (28.1%), followed by agricultural areas (17%) and herbaceous/woody

[218] The value of 324,692 ha covered by the sample differs very slightly from that of 324,581 ha in **Table 4.4** because of the data treatment done by Erdas Imagine when computing land-use changes matrices.

areas (0.5%). In sum, 82.4% of the area was coved in native vegetation comprising both forest formations and Cerrado areas. The low percentage of agriculture within these property boundaries demonstrate that 1985 was still an early stage of frontier colonization in the Chapada dos Parecis and BR-163 regions, which once more underlines the difference between this type of colonization and the colonization of the Amazon initiated in the 1970s. In 2015, the respective proportion of each vegetation cover had drastically shifted, the area occupied by forests falling down to 30.9% of the total property area and that of agricultural areas jumping up to 66.6%. Original Cerrado areas were wiped out almost entirely by the expansion of agriculture (2.2%).

The land cover change trend describes a strong and steady pace of agricultural expansion from the early stage of colonization in the 1980s up to a plateau in the middle of the 2000s. The area cleared for each time period declines steadily (except for 2000-2005) although the nature of the clearing varies. From 1985 to 2005, an additional 12.7% of the total available area was converted to agriculture on average every five years, with the highest conversion rate being for the 1985-1990 period (17.1%) and the lowest for the 1995-2000 period (9.4%). The 2000-2005 period presented a larger cleared area (11.9%) than the 1995-2000 period although one may have expected lower clearing rates after the Provisional Measure of 1996 increasing the LR requirement to 80% to forest areas. The heightened environmental policies enforcement in 2004 should also have contributed to reduce deforestation, but the 5-year estimates generated by the land-use change analysis do not allow a finer interpretation of this trend. Deforestation may have been concentrated in the 2001-2003 period and not in the 2004-2005 period. Morton et al. (2006) however showed that deforestation occurred throughout the 2000-2005 period with a marked peak in 2003. In the general context of deforestation in Mato Grosso, Azevedo (Andréa Aguiar Azevedo 2009) pointed

out that this period was one of "euphoria" among landowners who benefitted from the boom in world commodity prices at the time as well as an advantageous Brazilian real-U.S. dollar exchange rate. The opportunity costs of converting land to crop cultivation versus preserving land may have been too high as compared to other periods, tempting many farmers to clear land in anticipation of future gains two years down the line.[219]

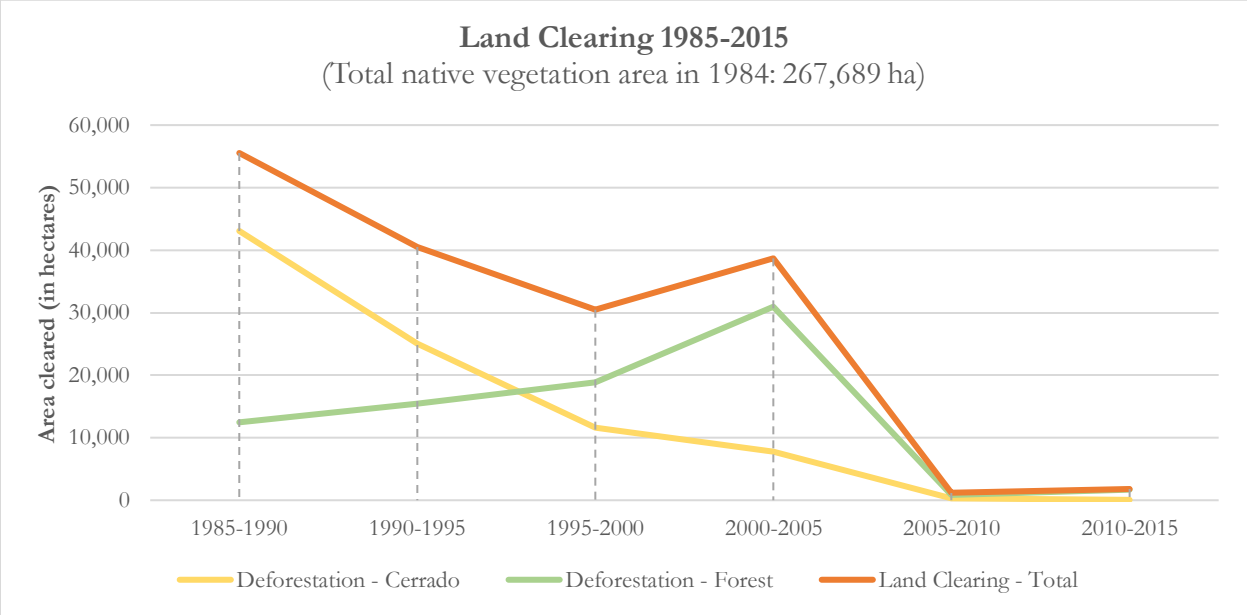


Figure 4.4. Evolution of land clearing rates for forest formations, Cerrado vegetation and total land clearing in rural properties of the sample (both BR-163 and Chapada dos Parecis regions). In 1985, the total native vegetation area (both forests and Cerrado) was 267,689 ha. By 2015, this area had fell down to 107,052 ha.

4.1.2. Clearing Cerrado first, forests second

The predominant type of land clearing also changed over time. Cerrado clearing was greater in the initial stage of frontier colonization, with 43,069 ha cleared in the 1985-1990 period (representing 49% of total Cerrado clearing over the 1985-2015 period) gradually falling to 7,728 ha (0.4% of total Cerrado clearing over the 1985-2015 period) in the 2000-2005 period (**See Figure**

[219] It takes two years between the clearing and the production of the first soybean harvest on the newly cleared plot. This is explained by the fact that soil acidity needs first to be corrected. As a result, farmers plant rice the season following the clearing for one or two years before being able to plant soybeans.

4.4). On the contrary, forest areas were gradually consumed as easy-to-clear Cerrado areas are becoming scarce. Only 12,467 ha were cleared in the 1985-1990 period (representing 15.5% of total forest clearing over the 1985-2015 period) while deforestation clearing peaked at 30,949 ha in the 2000-2005 period (representing 38.6% of the total forest clearing over the 1985-2015 period). In spite of potential income generation from logging, in the initial stages of colonization, the scarcity of machines (e.g. tractors) and capital to clear denser vegetation types made forests harder to clear than Cerrado areas. As farmers became increasingly capitalized in the 1990s and occupied most Cerrado areas on their property, they started to be able to clear forests more easily, which increased the pressure on forests.

Starting around the mid-2000s, land clearing trends came to a halt and the landscape within sample properties remained stable up to the end of the study period (**See Figure 4.3 & 4.4**). Cerrado land clearing neared 0% of the total Cerrado deforestation over the study period both in the 2005-2010 and 2010-2015 periods, something expected given the absence of any Cerrado vegetation left (Cerrado areas represented only around 2% of the total land cover starting in 2005). Forest clearing dropped from 30,949 ha in the 2000-2005 period to 850 ha in the 2005-2010 period and only increased very marginally in the period after, to 1,733 ha (in the 2010-2015 period). All municipalities and biomes together, agricultural activities occupied 216,246 ha (66.6% of the total property area) in 2015.

4.2. Regional differences between the Chapada dos Parecis and BR-163 region: land clearing differences linked to vegetation type

4.2.1. The BR-163 highway, an older frontier already partly cleared in 1985

Sample averages of land cover change obscure significant regional differences in the colonization history of the 7 municipalities included in the study (See Figure 4.7). The first major difference has to do with the timing of colonization of each frontier. One may observe that the municipalities of the Chapada dos Parecis had very little land under agriculture as of 1985. Properties in the easternmost municipalities of this area (i.e. Sapezal and Campo Novo do Parecis), closer to Cuiabá, only had between about 10% to 20% of the area under agriculture at the time while those in the westernmost municipality (i.e. Campos de Júlio) had not yet been cleared at all. The later start of colonization in the Chapada dos Parecis as compared to the BR-163 can partly be explained by the fact that this region was isolated vis-à-vis the main colonization axes represented by the Cuiabá-Porto Velho (BR-364) and Cuiabá-Santarém (BR-163) highways, until the MT-070 from Tangará da Serra to Campo Novo was built in the middle of the 1980s (Dubreuil, Bariou, Passos, et al. 2005). The road passing through this plateau branches out from the original path of the Cuiabá-Porto Velho highway to rejoin it later, in Vilhena (eastern part of Rondônia). The road initially did not connect to any major urban poles with logistical infrastructures such as a port. The BR-163 highway, on the contrary, connected Santarém in the North to the Paranaguá port in the South, passing through major production areas (Note: Santarém now has a soybean terminal built by Cargill in the 2000s). As a result of this infrastructure difference, the Parecis area[220] had not been subject of much economic interest until the 1980s when pioneers arrived to start crop cultivation

[220] Excluding Tangará da Serra and Diamantino.

(apart from being inhabited by the indigenous tribes of the Parecis plateau). In contrast, the BR-163 presented a longer occupation history in the 1980s, with the presence of a few colonizers doing cattle-ranching and a few farms. Because the military government was rather focused on the "myth" of the Amazon forest, which would hide abundant mining resources, it built the BR-163 as a way to get to Northern Mato Grosso and further into the forest, rather than exploiting the Cerrado (Le Tourneau unpublished). Northern Mato Grosso had experienced more colonization since the 1960s because of the several colonizadoras settled there.

4.2.2. Vegetation cover types affected the land clearing patterns (type and pace): fewer forests cleared in the Chapada dos Parecis

The second major difference between the two areas has to do with native vegetation cover types. Land clearing patterns between the two study regions vary both in terms of vegetation type and length of clearing. Properties in the Parecis area almost exclusively cleared Cerrado vegetation while those in the BR-163 areas combined both types of clearing (i.e. Cerrado and forest). These differences can partly be explained by differences in initial land covers. Properties in the municipalities of the Parecis area initially had a lower ratio of forests to Cerrado. Cerrado vegetation on Parecis properties represented 58% of the property area as compared to 12% in the BR-163 region. In municipalities of the BR-163, on the contrary, properties presented greater areas of forests: 58% as opposed to 31% in the Parecis area. This vegetation difference made land clearing easier in the latter area, landowners clearing large extents of Cerrado vegetation while mostly leaving forest areas intact. Over the 1985-2015 period, very little of the total area occupied by forests in rural properties was cleared in each municipality. The area of forests within the total property areas in these municipalities reduced by 5.5% in Campo Novo do Parecis (a 25% reduction in the forest cover initially present on private properties), 3.6% in Sapezal (a 12.2%

reduction in the forest cover) and 9.51% in Campos de Júlio (a 22.9% reduction in the forest cover) over the period of analysis. Properties there thus maintained a relatively stable forest cover over the study period at the exception of Campos de Júlio which passed from 41.4% to 32%.[221] As I will explore in Chapter 6, this may be the source diverging perceptions of the role of forests between farmers of the two region as farmers in the Parecis area may not have had the impression of "deforesting forests."

[221] Properties in Campo Novo do Parecis had 22% of forest cover in 1985 and 17.4% in 2015. Properties in Sapezal had 29.7% of forest cover in 1985 and 26.2% in 2015. Properties in Campos de Júlio had 41.4% of forest cover in 1985 and 32% in 2015.

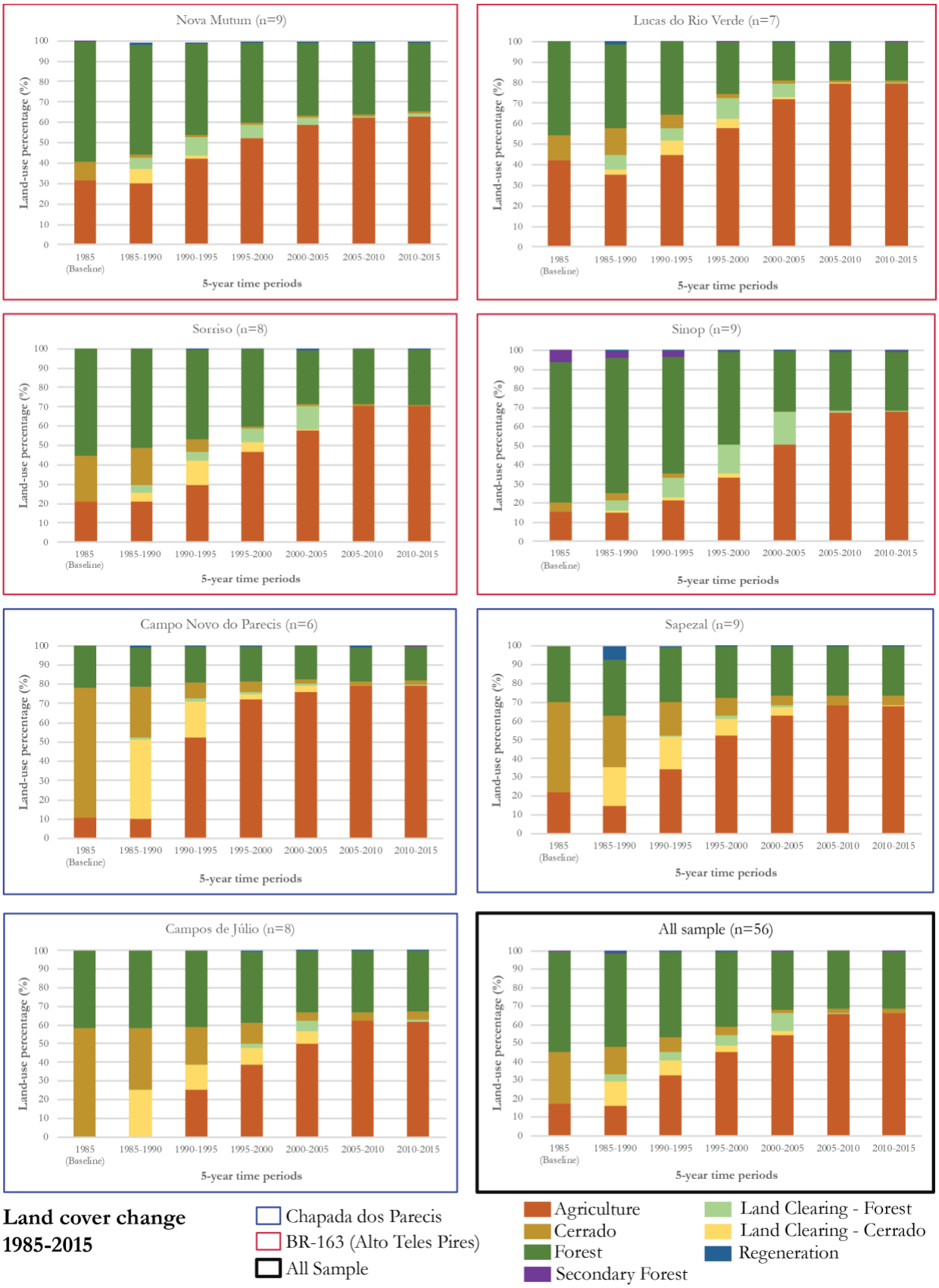


Figure 4.5. Land cover change between 1985 and 2015 in the 7 municipalities of the study.

Rural properties located in the BR-163 area faced a more balanced vegetation profile between forest and Cerrado areas. Forest areas represented 53.3% of the total property area in 1985 (excluding Sinop which had a 73.3% forest cover the same year). Although it is difficult to know exactly what land cover existed prior to agricultural areas of 1985, it is possible to hypothesize based on farmers' stories as well as the example of the colonization of the Parecis plateau that these were Cerrado areas (since they were easier to clear). As a result, the profile of vegetation in these municipalities (again, excluding Sinop) was a 50-50% balance between Cerrado and forests. Farmers in the BR-163 quickly occupied Cerrado areas (which represented a lower percentage of the total property area than in the Parecis region) as most municipalities reached less than 5% Cerrado cover by 1995.[222] As a result, when the soybean boom period occurred (approximately 1997-2004), forested areas were the main land cover susceptible to be converted to cropland. This explains why the bulk of forest clearing in the BR-163 area occurred between 1995 and 2005 and why remote sensing studies have detected high deforestation rates at that time (Gibbs et al. 2015; Morton, DeFries, Shimabukuro, Anderson, Arai, Espirito-Santo, et al. 2006).

The case of Sinop's properties is apart since forest cover was dominant and presented a different land-use trajectory than other properties in the municipalities of the BR-163 included in the study (**see Chapter 1**). Prior land use in this municipality was not based on extensive production systems such as cattle-ranching or soybean. Following the support of the COLONIZADORA SINOP, farmers experimented successively with different perennials (coffee, guarana, manioc) which did not require large areas as in the case of soybeans. When farmers in this area converted to soybeans around the second half of the 1990s the need for large areas of cleared land soared accordingly.

[222] Rural properties in Sinop, since the municipality is located within the Amazon biome dominated by forests, had already less than 5% of Cerrado cover in 1985.

As a result, the most intense deforestation period experienced by the municipality was between 1995 and 2005 when agricultural areas in rural properties passed from 33.2% to 67.4%.

The length of clearing also differed from one municipality to another. Properties in both frontiers, Nova Mutum, Campo Novo do Parecis, and Sapezal did not have major land cover change after 2000 whereas properties in all other municipalities only stopped around 2005. This contrasts with the municipal trend (See **Figure 4.5**), as **Figure 4.7** shows however that parts of Sapezal were intensively cleared in the 2000s (in the northwest part of the municipality). In the Parecis region, Campos de Júlio may have cleared sensibly more in the 2000-2005 given its "late" colonization start as compared to Sapezal and Campo Novo do Parecis. In the BR-163, it is more difficult to find a similar explanation to the extensive clearing of forests occurring in Sorriso, Lucas do Rio Verde, and Nova Mutum in the 2000-2005 period (See **Figure 4.6**). Sorriso, in particular, seem to have deforested extensively in the northern portion of the municipality enclosed in the Amazon biome. This extensive clearing is paradoxical in a way since there are stricter clearing limits in this biome than in the Cerrado biome.

4.2.3. Land clearing halt in 2005: Forests preserved in legal reserves in the Parecis area

Despite different initial land covers and land clearing patterns linked to their colonization trajectory, the major result is that agricultural expansion plateaued in all municipalities after 2005, coinciding with the heightened enforcement of environmental policies as well as the collapse of the soybean boom following the drop in the Brazilian real-U.S. dollar exchange rate (2004-2008 period) and global commodity prices for soybean and beef (2005-2007) (See Chapter 3). From 2005 on, all rural properties in the sample tended to preserve similar percentages of legal reserves

(LRs) regardless of their municipality (29% on average). Interestingly, in the Parecis area, rural properties tended to conserve legal reserves that encompasses or matches exactly their initial forest covers. In 2015, the average LR in Campos de Júlio was 36.7% (against 41% covered by forests in 1985), 31.4% in Sapezal (against 29.7% forest cover in 1985), and 19.6% in Campo Novo do Parecis (against 22% forest cover in 1985). Beside this, as **Figure 4.5** demonstrates, the percentage of forest cover in the Parecis area remains extraordinarily stable throughout the 1985-2015 period while the Cerrado areas disappear.

Although properties in the Parecis areas tend to have a mix of forests and Cerrado areas in their LRs, those of the BR-163 tend to be almost exclusively forests. In 2015, the average LR was of 19.8% in Lucas (against 45.5% forest cover in 1985), 35% in Nova Mutum (against 59% forests in 1985), 29.4% in Sorriso (against 55.5% in 1985), and 30.9% in Sinop (against 73.3% in 1985).

Figure 4.6 gives an idea of how properties in each municipality followed the municipal trend in land clearing over the years. Although the data in the sample are 5-year estimates and those in the MapBiomas v3.0 are year-by-year, one can observe that properties in the Alto Teles Pires region increased deforestation at a moment of extensive deforestation in their respective municipalities in the 1995-2005 period. The properties of Sinop's producers seem to follow a different direction than the municipal trend by increasing deforestation while the rest of the municipality does not. This can be explained by the fact that several of these municipalities are located at the border of Sinop, in the municipalities of Santa Carmem, Claudia, or Tabaporã. In the Chapada dos Parecis region, the sample properties seem to follow the municipal trend a little more than in the BR-163 area, except for those in Campos de Júlio. The difference between the property-level (in the

sample) and the municipal-level trends can partly be explained by the fact that the sample contains the same properties over time while the municipal data account for all the property creation and new areas turned into agriculture. It is possible that at the moment most deforestation occurred in the municipalities of the BR-163 and Chapada dos Parecis, during the soybean boom (1997-2004), properties of producers who arrived in the 1980s were mostly cleared. Thus, the municipal-trend may be the reflection of these producers buying new areas to expand activities, as well as an influx of new, more capitalized migrants in the 1990s converting other areas in the municipality. The comparison of municipal trends of **Figure 4.6** to the maps of deforested areas after 2000 (based on PRODES and PRODES Cerrado) on **figures 4.7 and 4.8** allow to see that most post-2000 deforestation occurred at the margins of municipalities, in the areas near the end of municipal boundaries.

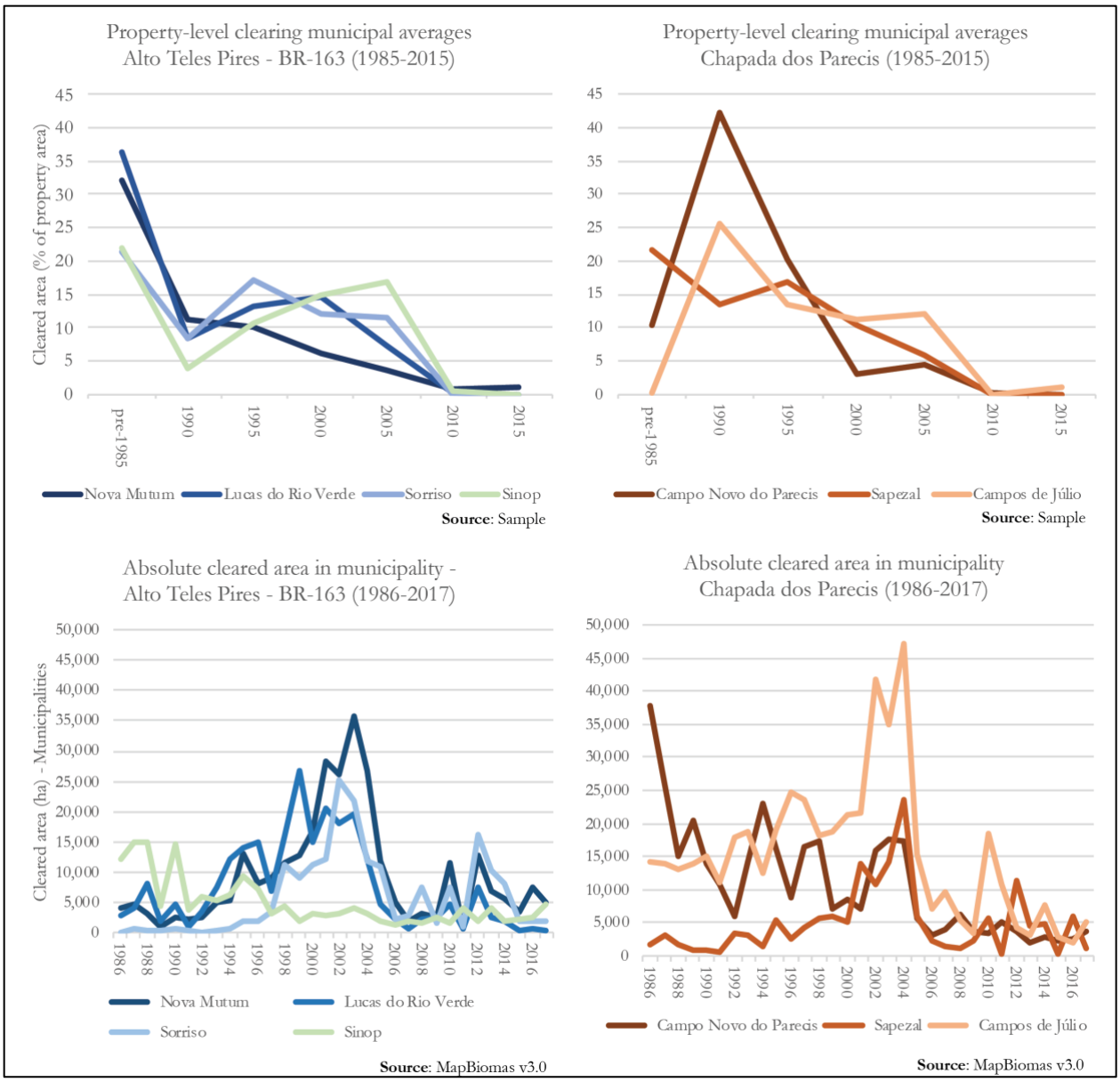


Figure 4.6. Comparison between the municipal-level average for property-level 5-year clearing estimates in the sample (in % of total property area cleared) (1985-2015) and the absolute yearly land clearing in each municipality (in hectares) (1986-2017). The absolute land clearing. The absolute land clearing data comes from the MapBiomas v3.0 dataset. The way I calculated land clearing for each municipality is only indicative of the trend and should not be read as the exact amount of clearing (Methodology explanation in footnote[223]).

[223] The MapBiomas v3.0 dataset provide land-use change matrices for each year from 1985 to 2017 for all Brazil. The land-use change data allow for a quick calculus of land clearing by calculating how much native vegetation cover turns into non-vegetation areas from one year to another. However, one limitation is that, from one time period to another, measurement errors or regrowth of vegetation areas (areas that may have previously been cleared) may be considered again as vegetation susceptible to be converted into agriculture again, creating an issue of double-counting of deforestation. Although it is uncertain how much this error may affect estimates (due to the particular methodology used here), it is likely to be minimally significant for the observation of broad municipal trends in land clearing.

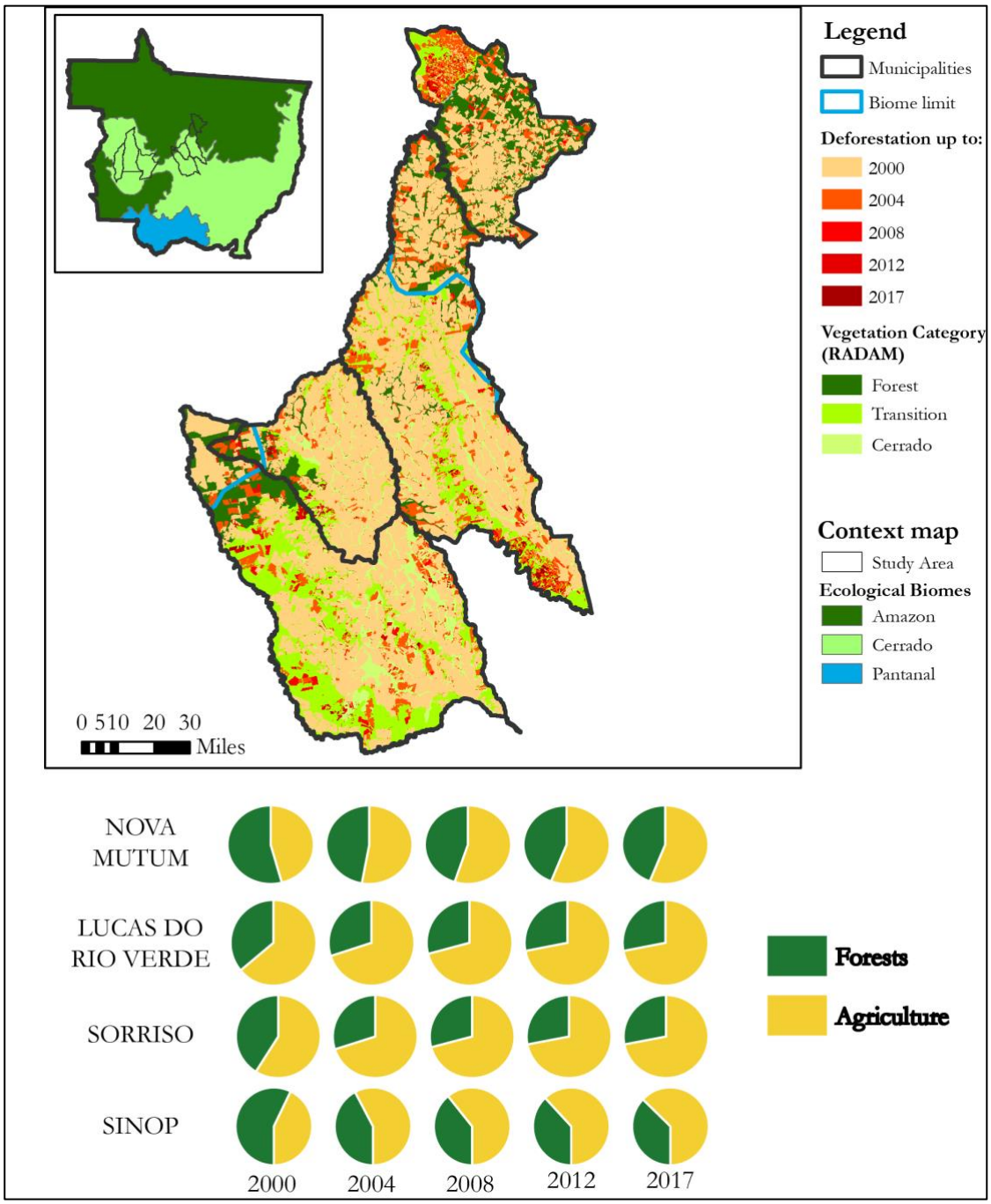


Figure 4.7. Native vegetation clearing in selected municipalities of the BR-163 highway study area. **Data**: (1) Deforestation data: PRODES and PRODES Cerrado; (2) Vegetation cover: RADAMBRASIL vegetation map.

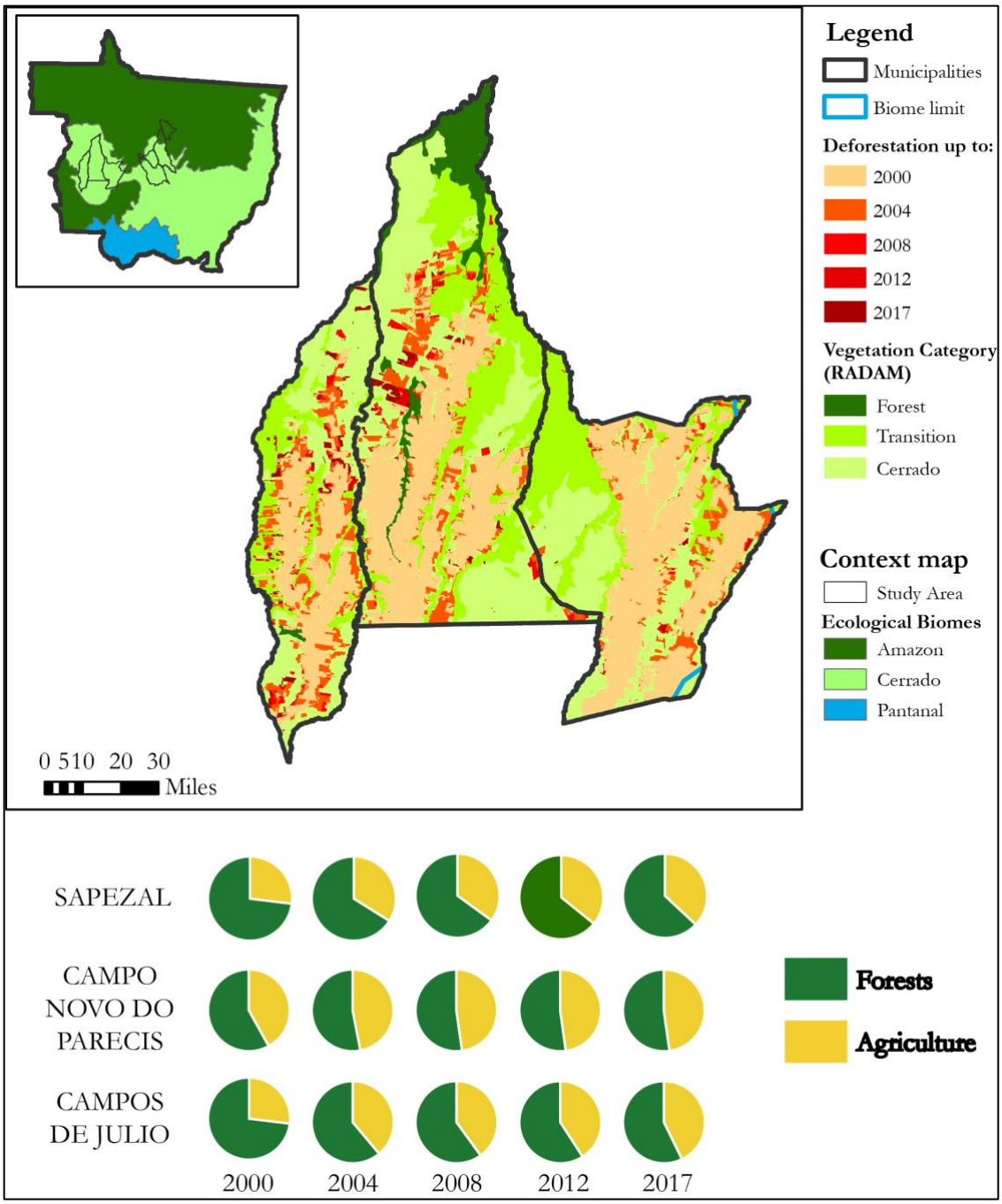


Figure 4.8. Native vegetation clearing in selected municipalities of the BR-163 highway study area. **Data**: (1) Deforestation data: PRODES and PRODES Cerrado; (2) Vegetation cover: RADAMBRASIL vegetation map.

4.3. MUNICIPAL- AND BIOME-LEVEL COMPLIANCE WITH THE FOREST CODE: OVERALL RESPECT OF CLEARING LIMITS IN THE CERRADO, DISRESPECT IN THE AMAZON

4.3.1. Biome-level compliance: no large differences in the amount of LR preserved between biomes

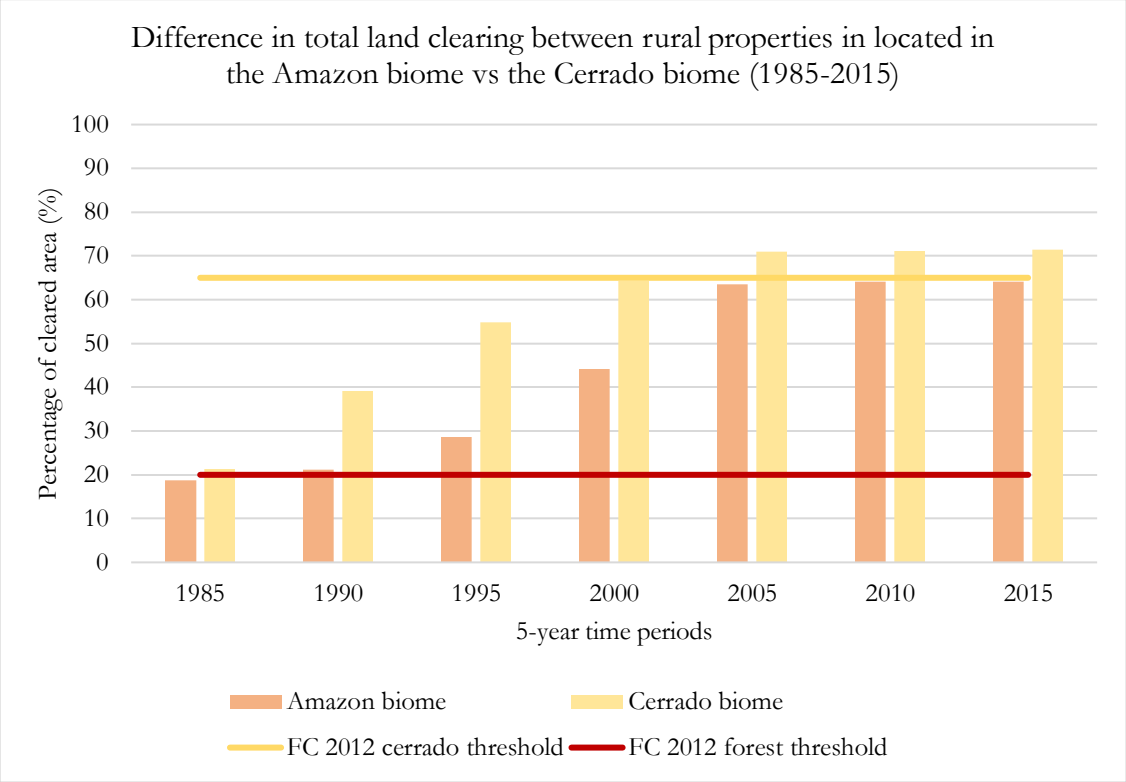


Figure 4.9. Difference in total land clearing between rural properties in located in the Amazon biome vs the Cerrado biome (1985-2015) with maximum percentages of authorized clearing (i.e. 65% for the Cerrado vegetation, 20% for the forest vegetation).

Surprisingly so, there are no large difference in the magnitude of preserved LR between rural properties located in the Amazon (n=10)[224] vs the Cerrado biome (n=46). Properties in the Cerrado biome cleared on average 71.5% of the initial native vegetation cover, leaving 28.5% preserved. Properties in the Amazon biome have cleared 64.1% and thus preserved 35.9% under native vegetation cover. In both biomes, landowners kept clearing despite the increased LR percentages applying to respective vegetation areas (**See Figure 4.9, 4.10, and 4.11**). In the Amazon biome,

[224] Of rural properties belonging to the Amazon biome, 8 are located in Sinop and 2 in Sorriso.

the LR percentage change from 50% to 80% for forest areas in 1996 did not result in any deforestation slowdown: Amazon-biome properties passed from 28.6% of cleared area in 1995 (right before the LR percentage change) to 64.1% in 2015. Farmers may have perceived the new limit of 80% LR as very unrealistic at the time since most of them had already cleared beyond when it was enacted. It is important to note that the "acceleration" that can be observed on **Figure 4.10** (below) has been accentuated by the fact that Sinop turned to soybeans starting in the late 1990s at a time where the opportunity costs of not planting soybean cultivation were very high.

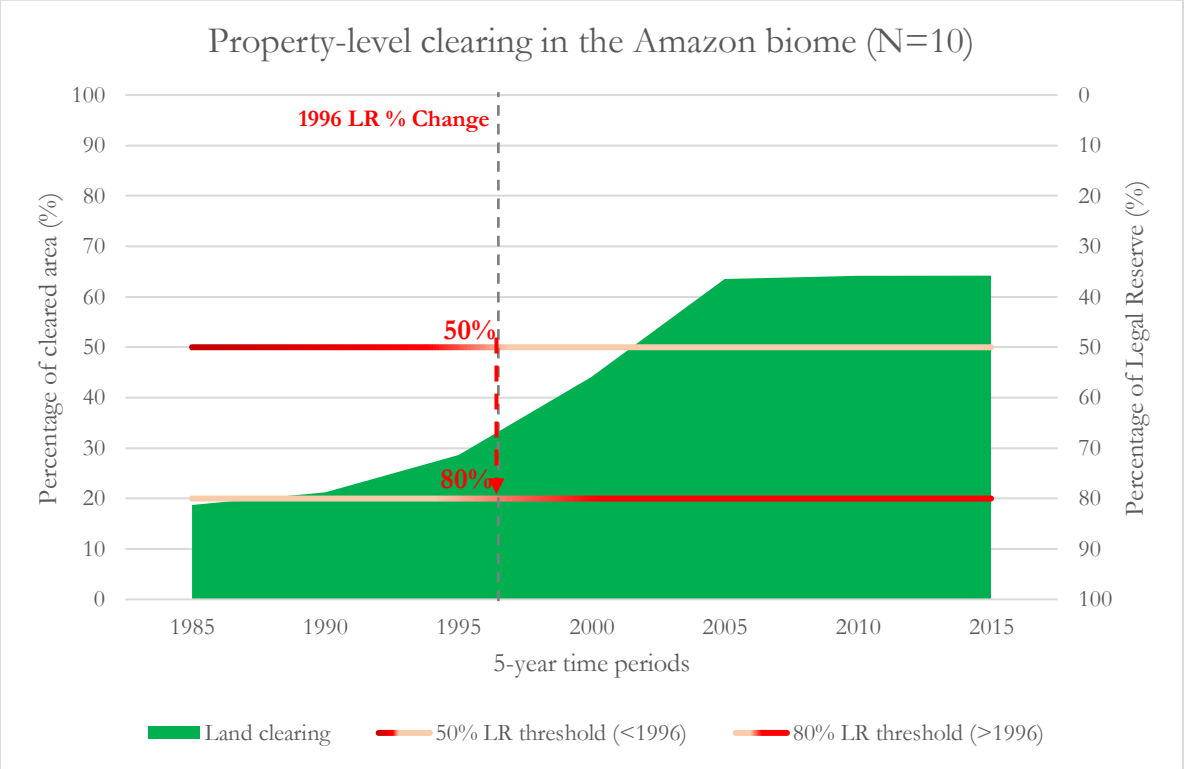


Figure 4.10. Percentage of cleared area for Amazon properties over the 1985-2015 period, showing the different requirements for the Legal Reserve changing after 1996 (vertical dotted line). Before 1996, landowners with properties in forest-dominated areas had only to keep 50% of native vegetation on their properties while after 2001, the government required them to preserve 80%.

For Cerrado properties, the change of LR limit (from 20% to 35%) occurred later in 2001. Nonetheless, farmers in these areas did not stop clearing at this point either. In 2000, rural properties had 64.2% of their area cleared on average while in 2015, this percentage had jumped

up to 71.4%. Contrary to rural properties in the Amazon biome which had already crossed their legally authorized clearing limits when the law changed, properties in the Cerrado crossed the limit after the change was enacted (**See Figure 4.11**). For increasingly capitalized soybean producers, the 2000-2005 period represented an era of unprecedented expansion for their business, with all indicators to the "green". The second half of the 1990s, characterized by the stabilization of the Brazilian real and the end of inflation both led to increased availability of rural credit and a (short-lived) drop in land prices, providing producers with new perspectives of expansion (Andréa Aguiar Azevedo 2009). When soybean (and beef) prices started rising in the early 2000s in combination with an increasingly advantageous real-dollar exchange rate, the profitability of soybean production reached an all-time high (Richards et al. 2012). Azevedo (2009) notes that expansion in Mato Grosso is especially strong in the BR-163 and Chapada dos Parecis during that "turning point" period of 1998 to 2002, in spite of FEMA's strengthened monitoring of fires and enforcement of environmental licensing.

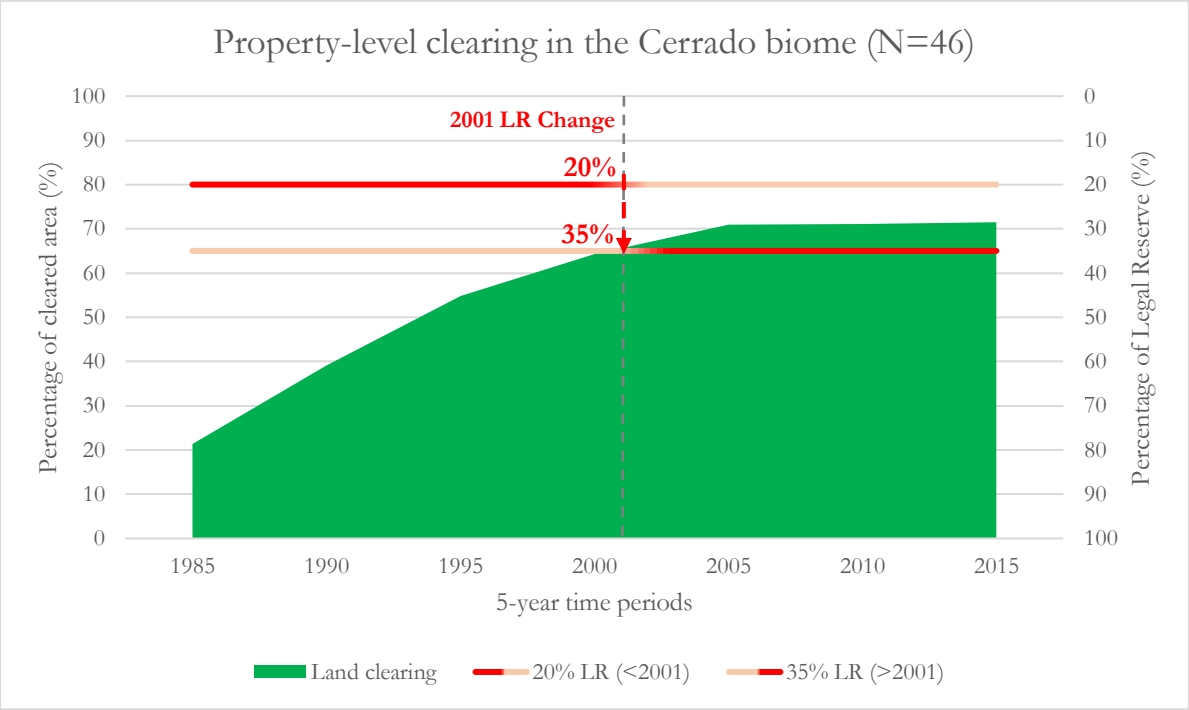


Figure 4.11. Percentage of cleared area for Cerrado properties over the 1985-2015 period, showing the different requirements for the Legal Reserve changing after 2001 (vertical dotted line). Before 2001, landowners in Cerrado-dominated areas had only to keep 20% of native vegetation on their properties while after 2001, the government required them to preserve 35%.

4.3.2. Municipal-level compliance: a generalized failure to respect the new LR limits

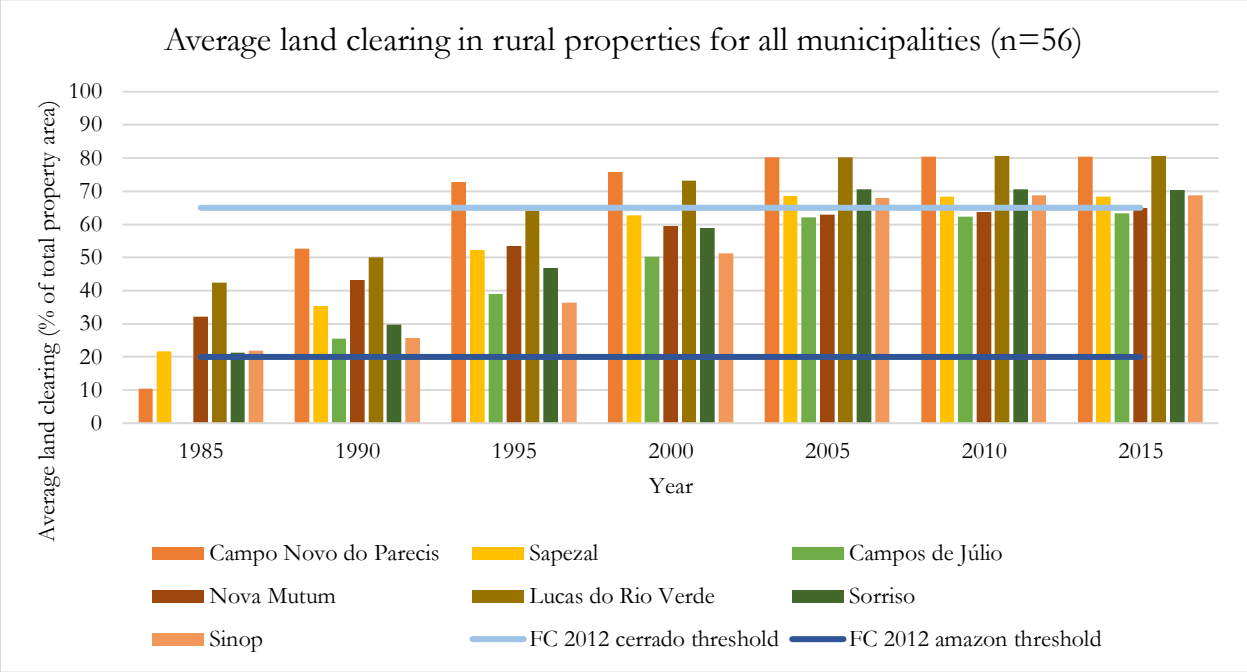


Figure 4.12. Difference in total land clearing between rural properties in located in the 7 municipalities included in the study (1985-2015) with maximum percentages of authorized clearing (i.e. 65% for the Cerrado vegetation areas, 20% for the Amazon vegetation areas). Note: Only Sinop is fully enclosed in the Amazon biome.

The comparison of FC compliance between properties of different municipalities is informative of the general tendency of the Amazon-Cerrado transition frontier. However, there is one caveat: the only municipality fully enclosed in the Amazon biome is Sinop while Sorriso has only a small share of its area pertaining to this biome. As a result, the reading of **Figure 4.12** with a bar indicating the maximum land clearing authorized by the FC is mostly intended for Sinop, where most properties are forest-dominated. This figure should neither be read as all properties do not comply with the 80% LR nor be read as all properties do not comply with the 35% LR.

Nonetheless, one striking observation is that most rural properties in all municipalities fall short of even complying with the 35% LR limit applying to Cerrado-dominated areas (65% authorized

clearing). Only Nova Mutum and Campos de Júlio have cleared areas under this limit. Rural properties in every municipality show similar proportions of cleared areas, which ranged in 2015 from 63.3% (Campos de Júlio) to 80.6% (Lucas do Rio Verde). One may however note that if we take out the two "extreme" examples of Lucas do Rio Verde and Campo Novo do Parecis (both nearing 80%), the range of variation is very narrow between 63.3% and 70.3% (Sorriso). The fact that municipalities having similar production systems and all leader in soybean production occupy land to the same extent should not be surprising in itself. However, it nonetheless is given the differences in clearing timing (some municipalities were colonized later than other), initial land cover (some municipalities had more forests than others), and trajectory of land-use (e.g. Sinop against the rest) existing between all municipalities. In spite of these differences, all agricultural areas in rural properties in these municipalities converge toward the same rate of occupation. This raises important questions. First, is there an optimal agricultural/conservation ratio in such properties that guarantee their long-term profitability? Second, do all properties in these municipalities face the same limits and if yes, which ones? Are there, for instance, soil capacity limits impeding further land-use? Or does this ratio reflect a compromise between farmers' imperative to produce and the respect of environmental regulations? In order to explore more these questions, it is necessary to examine in detail the history of land-use in each municipality of the sample.

4.4. LAND-COVER CHANGE AT THE PROPERTY-LEVEL: A COMMON PLAN FOR LAND CLEARING

The analysis of land clearing at the sample-, biome-, and municipal-level helps depicting a gradual and stable colonization process stretching over more than 20 years[225] until 2005. The general trend is toward the reduction of land clearing quantities over time although the phenomenon seems to bounce back in the key 2000-2005 period, which correspond to a time of relatively intense clearing for the municipalities of Sorriso, Sinop, and Campos de Júlio. However, this analysis does not help us understand whether this pattern was representative of how colonizers cleared their properties since the expansion of the frontier was the result of waves of colonizers arriving at different times. In other words, the analysis of individual trajectories of property clearing allows us to distinguish whether the municipal- and biome-level averages represent accurately the land clearing pattern of most properties or if it rather obscures a diversity of land clearing trajectories reflecting heterogeneous producer profiles clearing at different pace or timing.

Understanding this aspect is key to characterize the land clearing behavior of landowners: were landowners willing and able to clear their land as fast as possible with the sole goal to produce as much as possible, or were there careful planners who adapted their land clearing rates to their respective capacity and to seize market opportunities (e.g. higher soybean prices)? Furthermore, it can help us determine to what extent the surge of land clearing in 2000-2005 is due to new landowners arriving into the region to seize market opportunities or is due to the same landowners taking advantage of the legal instability of environmental policies before the PPCDAm.

[225] The analysis does not cover land clearing that occurred prior to 1985

I examine below what was the average length of land clearing for rural properties in the sample in order to determine how quickly a property reaches its last stage of the life-cycle with stable percentages of agriculture and LR cover. The timing of land clearing is also important to determine which properties complied with the respective FC limits of their time.

4.4.1. A slow start for most colonizers due to dire financial conditions (1980s to early 1990s)

Individual land-clearing trajectories of rural properties reveal a very mixed picture of clearing patterns (**See Figure 4.13)** as one would expect if we assume landowners respond differently to common factors (commodity prices, transport costs, environmental policies) based on their own characteristics (capital, technology, risk aversion, environmental values, etc.).

While some properties in the sample had not cleared any land by 1985, the majority of the sample had already started, thus demonstrating the important number of "pioneers" who arrived in the late 1970s and early 1980s in the sample. By 1985, 33 out of 56 landowners (58% of the sample) had already cleared more than 10% of their property (an average of 35% of the property was cleared then) and of those, 10 (17.8% of the sample) had already cleared over 40% of their property area, with one interviewee (n°10) who had cleared 90% but for a small 900ha property (**See Figure 4.13).** Importantly, this difference in starting points is not due to the size of the landholding as properties above 10% cleared in 1985 are on average 5,735 ha while those below 10% cleared are on average 5,883 ha. If we were to hypothesize that the size of the landholding reflects the initial capital of a farmer, then capital would not have influenced much the rate of clearing. In practice, however, the initial landholding size is only limitedly related to farmer's capital. Many farmers arriving on the frontier spent all their capital buying the land (and had little money left for clearing

activities) while others chose smaller land plots in order to save capital to invest later in clearing activities. As a result, many farmers did not have the means to clear large extents of land in the 1980s when capital was scarce (i.e. hyperinflation on the one hand, and low or no rural credit on the other).

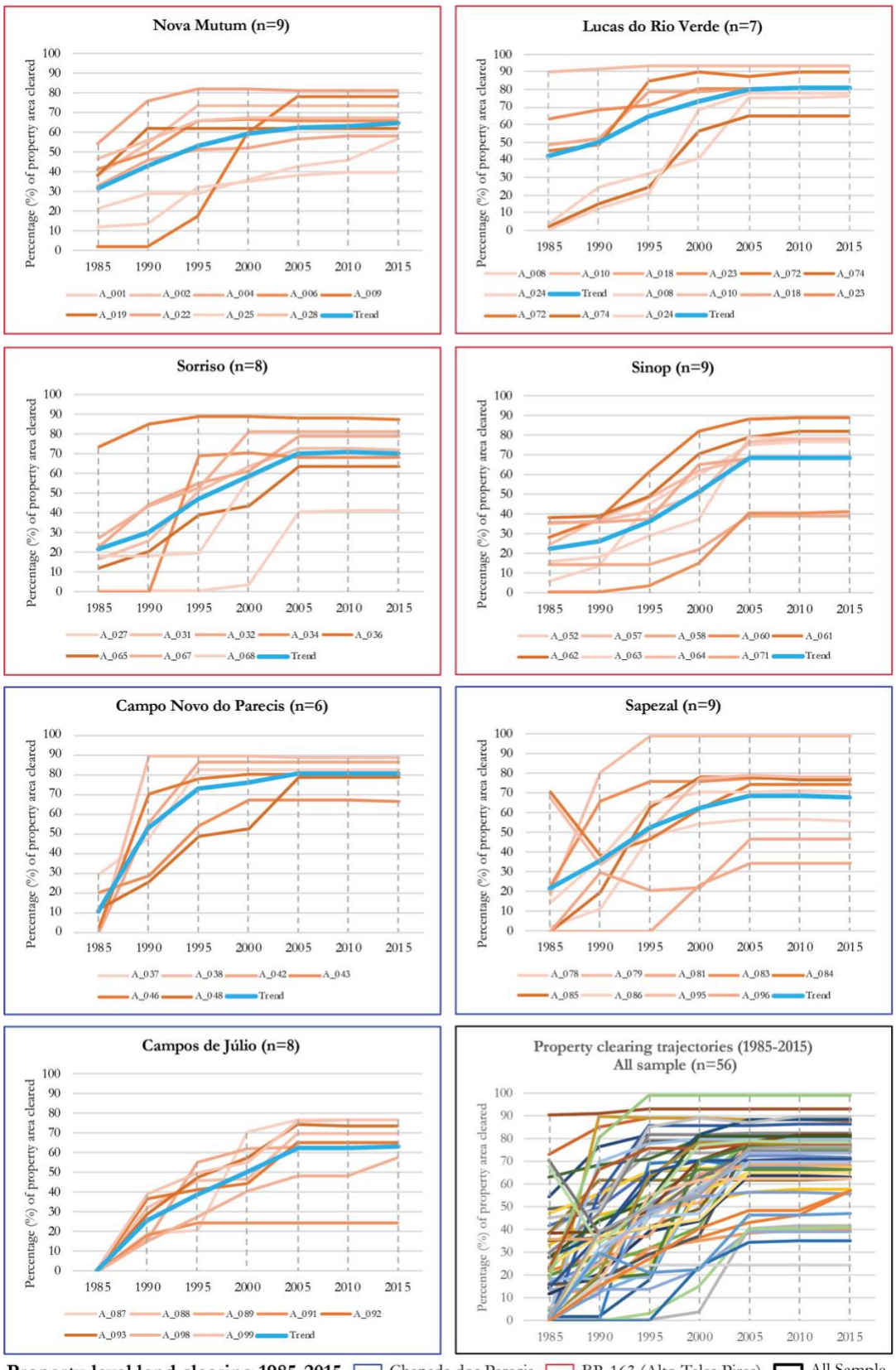


Figure 4.13. Property clearing trajectories for the 56 producers with available spatial data, broken down by municipalities. Each line represents the percentage of area cleared for the properties of one landowner family. In the rare instances a

curve is going downward, it means that a landowner has cleared some area during one period (usually by fire, the area was thus classified as agriculture) but ended up not using it 5 years later, thus permitting the area to return to some its previous state of vegetation (usually Cerrado).

The fact that landowners' ability to clear land was limited when they arrived in the frontier tends to be confirmed in the BR-163 region by the low clearing rates of the 1985-1990 period. Despite the fact that soybeans started to be planted around 1982 and 1983 in the areas, this period was extraordinarily difficult for farmers who struggled to access credit as federal incentives for colonization disappeared together with the military regime. As described by many interviewees, the situation only started improving around 1993-1994 as agricultural cooperatives from the South came into the area in the 1990s and helped funding farmers.[226] Financial conditions for land clearing only started to improve when the *Plano Real* helped stabilize the national currency (avoiding inflation) and after the *securitização* of rural debts (which concerned the renegotiating and restructuring of much of farmers' debts to the Central Bank). As one interviewee speaking about the clearing of his 1,900 ha property puts it, land clearing was slow because it was costly, advancing about 150 hectares per year according to him:

> *"We started to clear the property piece by piece, clearing more or less 150 ha per year. We cleared like this between 1992 and 2004. It was difficult and took time because it was* cerradão*. It was difficult to get funding. At the time, the C-Vale (which became BUNGE) was funding us but we finally got good funding resources, the "*securitização*," only after the* plano real *of 1994 by FHC. Many people became indebted as a result of this, but we were lucky to arrive in 1990 because the people who arrived in the 1980s was even more indebted. They had debt passive."*[227] *[009]*

[226] There were, however, already some cooperatives such as the COOPERLUCAs in Lucas do Rio Verde (VanWey et al. 2013)

[227] Original quote in Portuguese: "Começamos para abrir parte por parte a propriedade, abrindo mais o menos 150 ha / ano. Derrubamos assim entre 1992 e 2004. Era difícil e demorou porque era cerradão. Era difícil de conseguir recursos financeiros. Na época a C-Vale (que ficou a BUNGE) financiava mas tivemos bons recursos financeiros de novo, "securitização", só depois do plano real de 1994 pelo FHC. Muitos pessoas foram endividados por causa disso, mas tivemos sorte de chegar em 1990 de um modo porque o pessoal que chegou nos anos 1980 era ainda mais endividado. Tinham passivos de divida." [009]

In 1995, this farmer had 20% of his property cleared (380 ha) while in 2005 he had 78% (1,482 ha) thus clearing 1,102 ha in 10 years. His own estimate about land clearing is confirmed by the land-use analysis (**See Figure 4.12, Nova Mutum, line 009**). Interestingly, this farmer from Nova Mutum (southern part of the BR-163 study area) describes the difficulty of clearing *cerradão* which corresponds to denser forest formations in the Cerrado. This shows a key difference in how municipalities in the BR-163 region were characterized by large areas of transition vegetation, much harder (hence costly) to clear than typical Cerrado vegetation composed of small trees, grasslands, or bushes (the dominating landscape in the Chapada dos Parecis region).

In contrast, a landowner from Campo Novo do Parecis shared a story about the clearing conditions in this region:

> *"The clearing period was more or less between 1987 and 1993. It was low* cerradinho, *we cleared everything that was low* cerradinho *and left all the denser parts. In the municipality there was nothing, only half of the main street was paved. Trucks would get stuck in dirt a lot. When this happened, I had to leave my wife there and walk up to the nearest farm to ask help for towing the truck. As there were no dryers for rice, you had to transport the harvest in the truck together with the tractor in case it gets stuck in the mud. The bank would provide us with money for machines, limestone, and clearing, but no support for buying land"* [228]

The word *cerradinho* in Portuguese refers to the "small"[229] vegetation of the Cerrado, so the landowner refers to savanna formations such as *Cerrado denso*, *Cerrado típico*, *Cerrado ralo*,

[228] Original quote in Portuguese: "A época de abertura era mais o menos entre 1987 e 1993. Era cerradinho baixo, abrimos tudo que era cerradinho baixo e deixamos as partes mais grossa. No município tinha nada, só a metade da avenida principal era asfaltada. Atolava muito a camionete na terra. Quando acontecia, eu deixava a minha esposa lá e eu tinha que andar até na fazenda mais próxima para pedir ajuda para desatolar. Como não tinha secador de arroz, tinha que levar a safra no camião junto com o trator no caso que a camionete atolasse. O banco nos dava dinheiro para maquinário, calcário, para abertura de área, mas nada de apoio para comprar terras" [039]

[229] The suffix "-*inho*" indicates this.

parque de Cerrado, *palmeiral*, or *vereda* (**See figures 4.13, 4.14, 4.15**). This interviewee statement exemplifies how landowners in this area deforested the easier part in priority leaving denser forests standing until the late 1990s. In contrast to testimonies from the BR-163 region, it seemed that the financial support to landowners was good enough in the Chapada dos Parecis area to allow for clearing. This impression however may be due to the fact that clearing of Cerrado vegetation required relatively less money than clearing of forest formations, which would explain why at (hypothetical) similar levels of funding between the two regions, colonizers of the BR-163 complained more about the lack of financial support in that period.

Figure 4.14. Typical *palmeiral* in the Chapada dos Parecis region. Picture taken by the author in the Utiariti Indigenous Reserve located in the municipality of Sapezal (May 2017).

Figure 4.15. *Cerrado típico* in the Chapada dos Parecis region. Picture taken by the author in the Utiariti Indigenous Reserve located in the municipality of Sapezal (May 2017)

Figure 4.16. An idea of vegetation gradient in the Chapada dos Parecis region. Picture taken by the author in the Utiariti Indigenous Reserve located in the municipality of Sapezal (May 2017)

4.4.2. The generalized expansion of the 1990s: Agricultural crises and improving conditions for clearing

Despite improving conditions approaching the mid-1990s, farmers were also faced with the worst crisis of their history in the region because of a low soybean price and an excess of rainfall that caused many crop losses. As an interviewee reports it:

> *"In 1993-1994 there was a big crisis here, a combination of very low soybean prices (R$4/bag) and a lot of rain. Many went bankrupt and left, returning to the South. To give you an idea, the majority of people here arrived between 1986 and 1992. There was this crisis and after it improved a bit in 1998 and in 2000 agriculture really developed and expanded a lot. The 1994 crisis created a lot of individual indebtedness and people left because of this. The 2003-2004 crisis was important but not as much as that of 1994 because producers were more capitalized this time. In 2004, we had storage units and it helps. The ones who lost were those who did not have storage units"*[230] *[013]*

As a result, the trend of low clearing rates of the 1985-1990 period in the BR-163 area continued, to some extent, throughout the 1990-1995 period. This can be seen on **Figure 4.13** where the land clearing rates in 1985-1990 are much lower in the BR-163 region than in the Chapada dos Parecis where, unlike the BR-163, producers were only starting to settle and clear land there. As mentioned earlier, the clearing for this latter region during the 1985-1990 was important due to two factors: (1) the easy removal of Cerrado native vegetation as compared to the thicker forests landscapes of the BR-163 region; (2) the "fresh" arrival of capitalized colonizers. In the BR-163 region however, it is possible to observe considerable land clearing on the part of some properties in the 1990-1995 period. There are two reasons for this. First, rural credit started to be again available in the 1994-

[230] Original quote in Portuguese: "Em 1993-1994 teve uma grande crise aqui, um a combinação de preço de soja muito baixo (R$4/saca) e muita chuva. Muitos quebraram e foram embora, retornando no Sul. Para te dar uma ideia, a maior parte da gente aqui chegou entre 1986 e 1992. Teve essa crise e depois melhorou finalmente um pouco em 1998 e em 2000 a agricultura realmente desenvolveu e expandiu muito. A crise de 1994 criou muito endividamento e pessoal foi embora por causa disso. A crise de 2003-2004 foi importante mais não tanto como aquela de 1994, porque já os produtores estávamos mais capitalizados. Em 2004 tínhamos armazenagem e isso ajuda. Os que perderam são os que não tinham de armazenamento." [013]

1995 period (right after the 1994 agricultural crisis) and therefore farmers may have cleared extensive areas of land in 1994 and 1995 (which also matches with the timing of high deforestation peaks for the whole Amazon biome), contributing to "inflate" the estimates of the analysis for these properties in the 1990-1995 period simply because of two high clearing years. Second, the period was characterized by the arrival of new, heavily-capitalized farmers from the South who had heard of the region's agricultural potential and wanted to expand activities in Mato Grosso. In that period, several properties experienced rapid peaks of expansion. For instance, the property identified as 034 (Sorriso) passed from 0 to 69% of total cleared area within just that period, 052 (Sinop) passed from 13.1% to 45.1%, and 009 (Nova Mutum) passed from 1.9% to 18% during the same period. However, properties in the Chapada dos Parecis, in comparison, were clearing larger percentages of their area during this period which confirms that rural properties in the BR-163 were still recovering from the crisis.

As a result of these economic conditions, the majority of the expansion in the BR-163 (taking the area already cleared in 1985 as given) started thus partly in the 1990-1995 to really unfold throughout the 1995-2000 and 2000-2005 periods. Despite the agricultural crisis of 1994, most clearing trendlines in each municipality exhibited fairly straight shapes, demonstrating that the intensity and pace of clearing remained stable from 1990 throughout the year 2005 (**Figure 4.13**). The early signs of a slowdown in land clearing rates is however noticeable. In the BR-163, several properties in Nova Mutum started to plateau as early as in 1995. In the Chapada dos Parecis, the quick expansion of the 1990-1995 period (given the vegetation characteristics of properties) seemed to slow down as producers ran out of easy-to-clear areas as their cropland area started reaching forest formations on their properties. The 1995-2000 period is indeed the first where a

sizeable amount of forest clearing happened in this region (**Figure 4.7**). The slowdown was also due to the fact that producers ran out of fertile soils suitable for agriculture (Spera et al. 2014). The average percentage of area cleared in properties of the Chapada went from 10.7% in 1985 to 54% in 1995 (in less than 10 years) whereas the corresponding change in the BR-163 was 29.4% and 50.1% respectively. Soybean producers in the Chapada dos Parecis have therefore cleared more and much faster as compared to those of the BR-163 region to reach similar cleared extent in 1995.

Land clearing rates kept up in most municipalities during the 1995-2000 and the 2000-2005 periods. This fact is consistent with the positive economic conditions which producers benefitted from during the period (See Chapter 3), until difficulties started piling up, culminating in the 2004-2005 agricultural crisis. Soybean agriculture indeed became increasingly difficult in the late 1990s – early 2000s due to the appearance of soil diseases (nematoides), the soybean rust ("ferrugem asiática" in Portuguese), Neotropical Brown stink bug (*Euschistus Heros* – "percevejo" in Portuguese), and invasive weeds, each representing significant challenges to the pursuit of high yields (Contini et al. 2018).

The data on land clearing shows light evidence of a land clearing slowdown in Cerrado areas following any environmental policy changes occurring before 2004. Neither the impact of the 1996 Provisional Measure nor that of the 2001 Provisional measure increasing the LR percentages are clearly discernable, which is consistent with observations from previous studies focusing on the Amazon biome (Stickler et al. 2013). However, most municipal trendlines tend to break and have a smaller slope coefficient as the 1995-2000 period starts, such break occurring at different average clearing levels depending on the municipality. For two municipalities in the sample, however, such

policy changes occurred precisely when most landowners decided to expand. As can be seen on **Figure 4.17**, the majority of properties in Sinop cleared large shares of their total area when they converted from cattle-ranching to soybeans between 1995 and 2015. On the same figure, it is possible to observe that a majority of properties in Campos de Júlio decided to clear during that period. In all the other municipalities, such behavior is less widespread. Since such municipalities form a relatively homogenous space in terms of production systems and trajectories, this evidence somewhat invalidates the hypothesis of a strong policy effect after 1996.

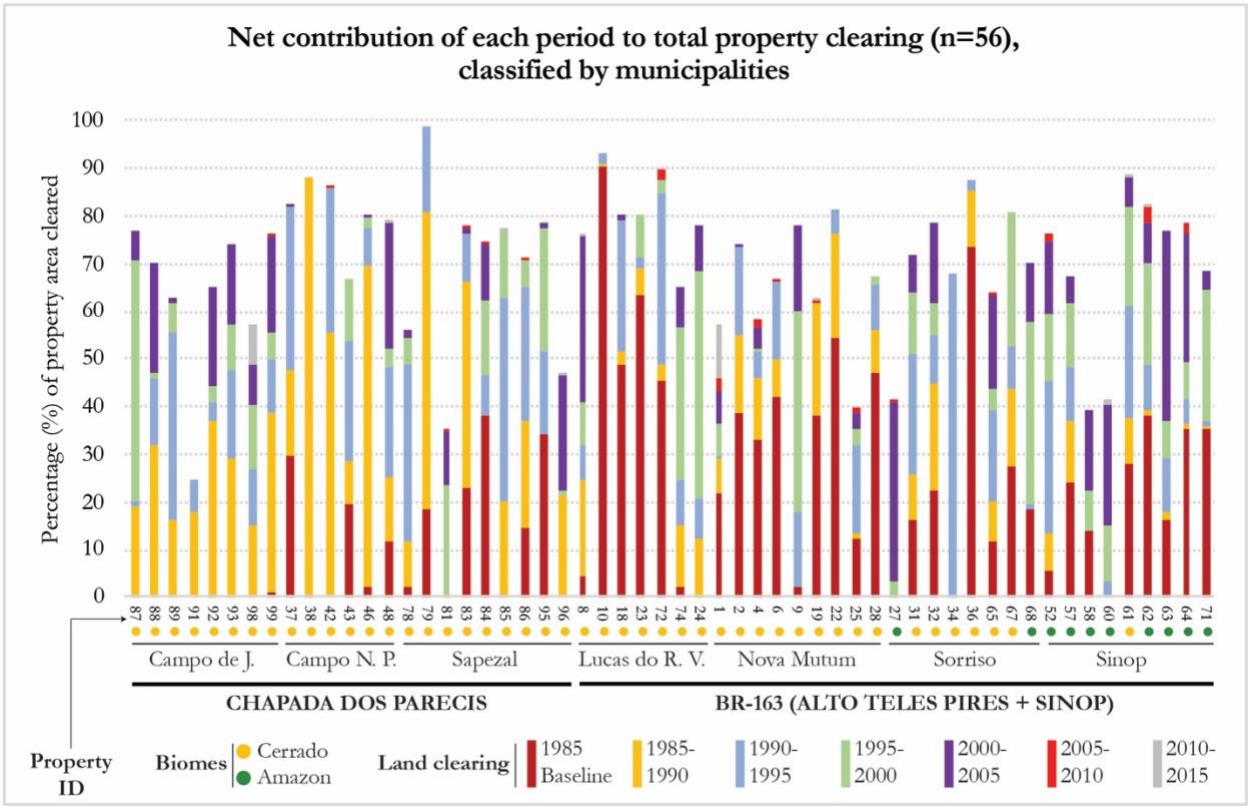


Figure 4.17. Net contribution of each time period to total property clearing in the 56 sampled properties, classified by municipalities (n=7) and by study region (n=2). **Note 1**: Since some properties had negative clearing values for some years (i.e. unused land cleared in previous time period which has recovered in the present time period), all these values have been subtracted to the previous clearing percentages in order to get the "net" clearing estimate for each time period. For instance, if a property cleared 62% in 1985-1990 and did not end up using all the land such that vegetation "recovered" partially in the meantime, the percentage of land cleared in 1990-1995 may have been -35%. If such is the case, this amount was subtracted to the 1985-1990 clearing estimate (becoming 27% instead) and a "0" was put for 1990-1995. Only three such cases of large magnitude (ranging from 10% to 30% negative clearing rates for one year) occurred in 1985-1990, with 6 others having minor negative clearing rates for some years, all inferior to 1%. **Note 2**: One property in Sinop is classified in the Cerrado biome because the property classification was based on the landowner's place of residence. However, only in three cases did a landowner live in a city located in another biome than the owned property.

4.4.3. Hitting the plateau in different years: can policies explain this change?

Clearing however comes to a complete halt in all municipalities after 2005. Since no year-to-year data are available here, it is difficult to interpret whether this interruption was due to the agricultural crisis of 2004-2005 or to the creation of the PPCDAm at that time.[231] Another important element is that, in 2005, most properties in the sample were already at the LR limit for their respective vegetation type or were well past it. This "plateauing" effect is however differentiated in space and time from one municipality to another, this can thus help determine what is due to a policy effect or what is due to a cropland scarcity effect. Many properties in the municipality of Nova Mutum, for instance, starts having stabilized land covers as early as 1995. Interestingly, they do stabilize at very different land clearing levels over the 1995-2015 period: one property oscillates between 30% (1995) and 40% (2015) of its total area (ITW n°025), another around 51% (1995) and 58% (2015) (ITW n°004), while others permanently remain at 61% (ITW n°019), 66% (ITWs n°006 and n°028), 73% (ITW n°002), and 81% (ITW n°022).

This diversity of land clearing ceilings may illustrate the variety of landowners' preferences with respect to land clearing levels or responses to environmental policies, but may also show that properties reached different land cultivation limits depending on their location and vegetation type. The fact that these properties did not clear further right when expansion conditions were best may also illustrate a shift in production systems (e.g. from expansion-based production to intensified modes of production) or actual soil limits (See Chapter 5). It is also possible that both factors came

[231] Year-to-year deforestation estimates may have helped determine whether the bulk of clearing during the 2000-2005 period occurred at the beginning of the period during the agricultural soybean boom or at the end of the period after the reinforcement of environmental policies had been enacted.

into play: if farmers were not able to find more good quality soils on their property, they may have been compelled earlier to adopt production practices that optimized their existing planted area or this may have prompted them to buy or rent additional land elsewhere. Similarly to Nova Mutum, many properties in Lucas do Rio Verde and Campo Novo do Parecis started plateauing in 1995 but at much higher land clearing levels, around 70-90% of cleared area. Assuming these frontiers adopted intensified production systems around the same period (the mean year of adoption of no till practices in the sample is 1996), an explanation of the difference in land clearing levels based on soil limits is not well supported. It would mean that a great number of properties in these municipalities, of different size (the largest taking probably more time and resources to clear), all reached the maximum cultivable area at the exact same time.

Given the variability of plateaus reached by properties, an hypothesis based on biophysical limits is at best incomplete. On the contrary, the fact that properties with both small and large extent of cleared land stop expanding at the same time supports the idea of changing financial conditions and production systems.

4.5. RELATIONSHIP BETWEEN PROPERTY SIZE AND LAND CLEARING

To further examine the possibility that such clearing levels and timing depend on landowners' characteristics, I classify in **Figure 4.18** the land clearing trajectories of landowners based on their property size by creating 4 classes: (1) properties under 2,000 ha; (2) properties between 2,000 ha and 5,000 ha; (3) properties between 5,000 ha and 10,000 ha; and (4) properties above 10,000 ha. First, all property size classes present a mixed set of trajectories combining sharp and rapid clearings as well as steady and gradual ones. It seems however that periods of sharp and rapid

clearings (loosely defined here as clearings superior to 30% to 40% of the property area within a 5-year time period) are more common in properties under 5,000ha. As the size of the property increases, this trend diminishes to almost completely disappear in the category of properties above 10,000 ha. This is not a surprising result to the extent that a smaller properties are easier and faster to clear than larger ones. The more balanced clearing across time periods for larger properties is further confirmed in **Figure 4.19** where we can see that the total clearing of such properties occurred over 4 to 5 different time periods. On the contrary, smaller properties tended to be cleared over 3 time periods on average. This figure reveals slightly different land clearing thresholds depending on the property size. Larger properties tend to clear less area but the range between high and low land clearing thresholds reached by individual properties in a same group is roughly the same across the spectrum of property sizes.

Second, properties of different size plateaued at different times. As can be seen on **Figure 4.19** smaller size properties tend to plateau earlier than larger properties. 13 out of 35 properties under 5,000 ha plateaued as early as 1995, and 7 out of 35 plateaued by 2000. In contrast, only 2 out of 21 properties above 5,000 ha plateaued by 1995 and 3 out of 21 plateaued by 2000. This means that 42.8% (15 out of 35) of properties under 5,000 ha and 76.2% (16 out of 21) of properties above 5,000 ha plateaued only after 2005. Therefore, although a majority of properties only stopped clearing in around 2005, it is markedly more the case for larger than smaller properties. This impression is further confirmed by **Figure 4.19** where large 2000-2005 clearings (in purple on the figure) tend to be more frequent for properties over 5,000 ha. Properties under 5,000 ha present more frequent and large clearings for the 1995-2000 period (in light green on the figure).

Finally, one clearly discernable pattern is that of 10,000 ha properties. Almost all properties in the group of 10,000 ha or more accelerated land clearing in the 2000-2005 period, exactly after the LR percentages for forest-dominated and Cerrado-dominated areas had changed. This suggest that these producers were probably most able to invest in land clearing when soybean production conditions were excellent (early 2000s) and decided to seize that opportunity regardless of policy changes. However, only 2 out of the 8 properties end up not respecting a 35% LR limit while all the others comply with it. Without information about whether these land clearings were duly authorized by environmental bodies at the time, it is difficult to conclude whether the other properties in the group illegally cleared land.

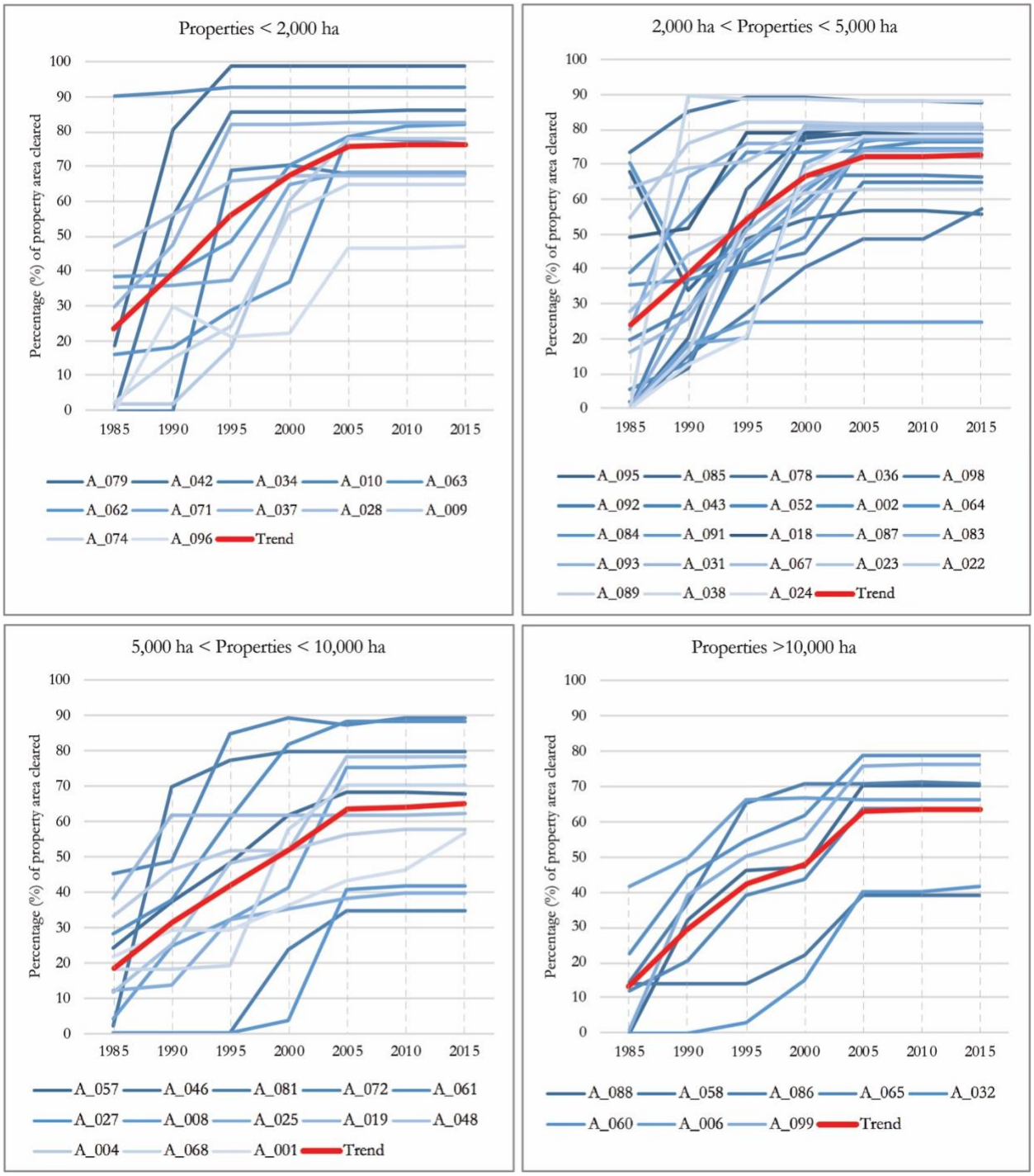


Figure 4.18. Land clearing trajectories at the property-level broken down in four size classes: (1) properties under 2,000 ha; (2) properties between 2,000 ha and 5,000 ha; (3) properties between 5,000 ha and 10,000 ha; and (4) properties above 10,000 ha.

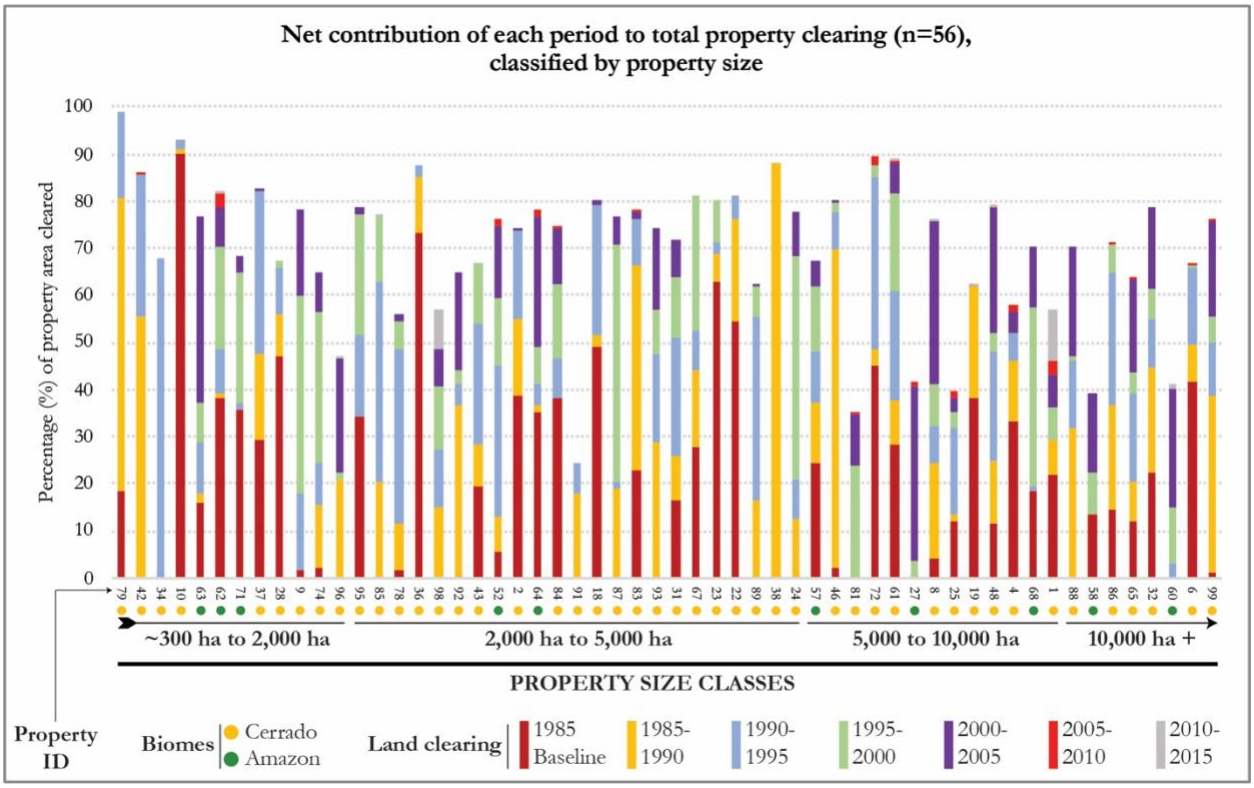


Figure 4.19. Net contribution of each period to total property clearing in the 56 sampled properties, classified property size (smallest to largest values from left to right). The leftmost property is 366 ha and the rightmost property is 35,932 ha.

Third, in spite of the differences, it is still the similarity of land clearing patterns across property sizes that strikes most. An overwhelming majority of properties, regardless of municipalities and biomes, consolidate around 70 to 80% of total clearing. To some extent, the property size class ranges are arbitrary and try to reflect some reality of the field. Many were the farmers who shared their assessment that it is necessary to own at least 1,000-2,000 ha in order to be able to compete in today's market conditions. However, the data shown on **Figure 4.18** and **Figure 4.19** may not reflect accurately the total property area owned by a landowner since they may own multiple properties. If small properties in the sample are owned by individuals who actually owned several properties, then the relative capitalization of landowners inferred based on the property size included in the sample may be invalid. In order to check for this, I calculated the percentage representativeness of the property in the sample against the self-reported total area owned and total area managed by landowners, classified based on the size of the sample property (and not their

self-reported total property size) (**See Table 4.6)**. What the analysis reveals is that sampled properties under 2,000 ha only account for 54% of what landowners really own, and even fewer than what they really managed (45% of what they own and rent). As a result, the clearing patterns for properties under 2,000 ha may in fact be influenced by the fact landowners are more capitalized in reality than what they appear to be if we were just looking at the sampled properties. Since most sampled properties seem to be owned by landowners who hold more properties than just one, the land clearing patters can be interpreted as reflecting more the constraints related to area and biophysical factors rather than constraints of capital, or strategies to invest in other lands. It would be therefore -at worst- incorrect to infer either that smaller properties were cleared faster by smaller landowners or that smaller properties plateaued earlier because of capital constraints.

Property size class	Average Sampled Property Size	Average Owned Property Area	Averaged Representativeness (Total Property Owned)	Average Representativeness (Total Property Managed)
< 2,000 ha	1,284 ha	3,570 ha	54 %	45 %
2-5,000 ha	3,104 ha	7,090 ha	68 %	61 %
5-10,000 ha	6,950 ha	12,601 ha	79 %	79 %
>10,000 ha	18,427 ha	32,895 ha	69 %	69 %

Table 4.6. Representativeness of sampled properties with respect to the total area owned and managed by landowners of different property size class (The property size class of landowners is based here on the sampled property, not on the total property they own). **Note 1**: The objective of this table is to measure the representativeness of the properties included in the spatial analysis instead of the representativeness of landowners by total area. **Note 2**: Property managed includes both the properties owned and rented by landowners. **Interpretation**: small properties included in the spatial analysis tend to only represent half (54%) of what landowners really own, and 45% of all the area they manage. The sample thus underestimates the real size of landowners' estates.

4.6. PROPERTY-LEVEL COMPLIANCE WITH THE FOREST CODE

4.6.1. Compliance under two versions of the FC for forest-dominated areas and Cerrado-dominated areas: a majority disrespected LR limit changes in both areas

The similarity in land clearing patterns across municipalities and biomes that have different legal limits to clearing questions all the more the real efficacy of environmental policies in the Amazon-Cerrado transition areas of Mato Grosso. The **tables 4.7** and **4.8** describes the compliance level of properties included in the sample based on two different version of the FC for forest-dominated areas versus Cerrado-dominated areas.[232] In 2015, 33 out of 46 properties in Cerrado-dominated areas were non-compliant with the 2012 FC (a number going down to 12 out of 46 properties if we take into account the 20% LR criterion in effect before 2001). In forest-dominated areas, all properties (n=10) were non-compliant with the 2012 FC in 2015 (a number falling down to 7 with the LR criterion in effect before).

CERRADO BIOME & VEGETATION	Before 2001 criteria (RL=20%)				After 2001 criteria (RL=35%)		
Area cleared	1985	1990	1995	2000	2005	2010	2015
<=65%	42	38	29	22	13	13	13
>65% to <=80%	3	4	9	13	21	21	21
>80%	1	4	8	11	12	12	12
Total compliant	45	42	38	35	13	13	13
Total non-compliant	1	4	8	11	33	33	33

Table 4.7. Number and area cleared of properties located in the Cerrado biome in compliance with the LR limit of Cerrado-dominated areas (20% before 2001 and 35% after 2001) at different time periods.

[232] For the purpose of the analysis, the location of a property into either a forest-dominated area as opposed to a Cerrado-dominated area was based on their location into the Amazon and Cerrado biome, respectively. This does not accurately reflect the real legal compliance of such properties as in either biomes, a property can be considered as belonging to a forest-dominated area or a Cerrado-dominated area for purposes of calculating the LR and compliance with the FC. Properties in the BR-163 area, a region characterized by more prevalent transition vegetation areas, but located in the Cerrado biome are more likely to be subject to the 80% LR limit (because transition areas are considered to be forests) than properties in the Chapada dos Parecis.

FOREST BIOME & VEGETATION	Before 1996 criteria (RL=50%)			After 1996 criteria (RL=80%)			
Area cleared	1985	1990	1995	2000	2005	2010	2015
<=20%	6	6	4	2	0	0	0
>20% to <=50%	4	4	6	3	3	3	3
>50%	0	0	0	5	7	7	7
Total compliant	10	10	10	2	0	0	0
Total non-compliant	0	0	0	8	10	10	10

Table 4.8. Number and area cleared of properties located in the Amazon biome in compliance with the LR limit of forest-dominated areas (50% before 1996 and 80% after 1996) at different time periods

Detailing compliance levels between two version of the FC (pre and post LR-limit change from 50 to 80% in forest areas and 20% to 35% in Cerrado areas) allows to analyze which properties turned non-compliant as a result of the percentage change or as a result of further ("unauthorized") deforestation (See **tables 4.7 and 4.8**). In Cerrado-dominated areas in 2000, where the LR percentage change occurred in 2001, 22 properties had more than 35% LR, 13 properties had more than 20% LR (but less than 35%) and 11 properties had a LR lower than 20% (**Table 4.7**). In 2005, there were only 13 properties remaining with a 35% LR, 21 with a 20% LR and 12 with a LR lower than 20%. This practically means that 13 properties remained in compliance throughout the period, regardless of the limit. However, 9 properties decided to deforest and go below a 35% LR when the law changed in 2001 and 1 decided to deforest resulting in a LR below 20% although this was unauthorized throughout the period.

One can witness a similar pattern in forest-dominated areas with only 2 properties remaining compliant throughout the period (**Table 4.8**). In 1995, all properties were compliant with the 50% LR in effect at the time. By 2000, however, 5 properties decided to clear over 50% of their area, and 3 properties had become non-compliant as a result of the LR % change from 50 to 80%. By 2005, the two remaining properties that had a LR of 80% decided to clear up to 40% of their area, leaving no properties compliant with the FC.

4.6.2. Limitations to the analysis and producers' compensation of LR deficit with other areas

A majority of properties in both locations have therefore chosen not to respect the LR, further confirming the idea that early environmental policy changes in 1996 and 2001 had no significant impact on the land clearing trajectory of farmers in the Amazon-Cerrado transition areas. The discussion of property-level compliance with the FC has however several limitations. First, the LR limit increased over time and might have made many landowners non-compliant simply as a result of the percentage change. Farmers who had respected the limits in effect at the time they cleared may have done nothing wrong to put themselves into non-compliance. Second, the convoluted evolution history of the FC at both the federal- and state-levels may have led landowners to think that it was possible to clear more than what was authorized on their land, provided that they compensated with equivalent forest cover on another property having an excess of it (with respect to minimum requirements). The possibility of compensating forest covers deficits and excess between rural properties was first "offered" to Mato Grosso landowners with a law 2000 (See Chapter 3) enabling them to compensate deficits by the donation of an area located within a Conservation Unit (UC).[233] As noted in Chapter 3, this mechanism was never used at a significant scale. The MT-Legal later offered landowners the possibility of regularizing their environmental deficit by paying a sum of money into a State Environmental Fund (FEMAM). There is however no evidence that this mechanism may have caused further deforestation in the brief time it was in effect. Furthermore, no properties changed of compliance category during the 2005-2010 period (**See tables 4.7 and 4.8**).

[233] This, however, relies on the possibility that a landowner has an unlawful area located in a Conservation Unit.

Third, the new FC of 2012 authorizes landowners to compensate their deficit by excess LRs in other properties they own (provided they fit the compensation conditions set by the FC), or by buying CRAs to other landowners. This analysis only limitedly captures this aspect. During the interviews, landowners were asked whether they compensate their deficit in LR with other properties. 21 landowners (out of 104) declared having compensated their deficit with another property while 1 declared having plans to do so.[234] Of the 43 producers found non-compliant under the 2012 FC in the property-level analysis (out of a total of 56 producers) 12 have declared using compensation for their LR deficit. It is not clear what proportion of farmers compensated with the then-available mechanism of FEMAM or with excess native vegetation available in another property (either theirs or that of another producer). Interestingly, 1 farmer found compliant in the analysis declared using compensation. This is most likely due to a LR deficit that this landowner has on another property. It remains also uncertain how the 30 other producers address their non-compliance status.

Finally, this analysis is limited because it analyses property-level compliance in Cerrado and forest areas based on the biome boundaries and not the actual classification of the property into either forest-dominated or Cerrado-dominated areas. Many properties located in the Cerrado biome, for example, could have fallen into the forest-dominated category based on whether they were in forest transition areas. However, since the location characteristics is based upon the interpretation of the state environmental body (relying on the RADAM mapping, mostly) and on a case-by-case basis, it is virtually impossible to draw clear conclusions about the real legal status of numerous properties.

[234] There is no property-level data for spatial analysis for 8 these 21 producers.

4.7. EXAMINATION OF PRODUCERS' PERCEPTION OF THE INFLUENCE OF ENVIRONMENTAL POLICIES ON THEIR PRACTICES

One important aspect in assessing the effectiveness of environmental policies is whether local actors *perceived* such policies as having an impact on their behavior. In this section, I examine whether soybean producers have perceived any consequences to a variety of environmental policy measures. In analyzing the results, I compare whether compliance with the FC is higher in municipalities where producers had a stronger perception that environmental policies has an impact. I will understand environmental policies as any measure taken by the public (federal, state, municipal) or private sector to foster the preservation of native vegetation (e.g. the compliance of landowners with the FC) by landowners or sanction them otherwise. Some elements discussed in these paragraphs may thus not sound like what environmental policies typically are, but every measure examined has an impact (at least theoretical) on how landowners preserve the environment (or prevent excessive chemical contamination). During the interviews, I asked farmers to provide their assessment of the influence of policies over the *compliance of landowners with environmental requirements within their municipality*. Importantly, I did not ask them what they thought the impact of such policies had on their own compliance since I wanted to avoid them to experience any feelings of guilt that may bias the results. For instance, I did not want to ask them first whether their property had received an embargo from IBAMA and then ask them whether they found that effective or not in getting them into compliance. On the contrary, I asked first questions about their perception of environmental policies' compliance for the overall municipality and only then did I ask whether they had ever received an environmental fine or embargo.

The question was structured as a 1 to 5 Likert-scale, 1 meaning that policies had "no influence on the environmental compliance of landowners" and a 5 meaning that policies had a "strong influence on the environmental compliance of landowners" (i.e. in the sense of deterring them from deforesting). The influence of the 7 following elements (in order) on environmental compliance was evaluated:

1. Environmental fines by either IBAMA (federal) or SEMA (state)

2. Embargo on rural property imposed by IBAMA (federal)

3. Suspension of rural credit imposed by IBAMA (federal)

4. The presence of enforcement activities by IBAMA (federal)

5. Prohibition of soybean purchases by the multinational trading companies through the Soybean Moratorium

6. The role of the municipality in promoting environmental compliance (through information and support to landowners)

7. Environmental fines by the INDEA (state) for non-compliance with chemicals use

4.7.1. Municipal-level results

Fines. The results to this question are presented in **Figure 4.20** and ordered per policy measures. It shows that landowners on average perceived policies differently depending on the municipality where they reside. Interestingly, but perhaps not surprisingly, the perception that fines by IBAMA or SEMA were influential in incentivizing landowners to comply with the FC is higher in municipalities that deforested later than others (e.g. Campos de Júlio and Sinop) and, to a lesser extent, that were last to stop (e.g. Sorriso). Thus, it is possible that more deforestation events in a given municipality around the 2000s meant for landowners a higher perceived risk of receiving a

fine (in 2004, the DETER system was functional and the PPCDAm was initiated). Landowners in municipalities that deforested over the authorized limit may also feel threatened, as the high score for Campo Novo do Parecis shows (i.e. properties in this municipality were found to have cleared 80% of their area on average). Overall, the general relationship that seems to emerge is that perceptions of IBAMA fines tend to be higher in municipalities both located in the Amazon biome and which deforested intensively late (in the 2000s) as compared to others.

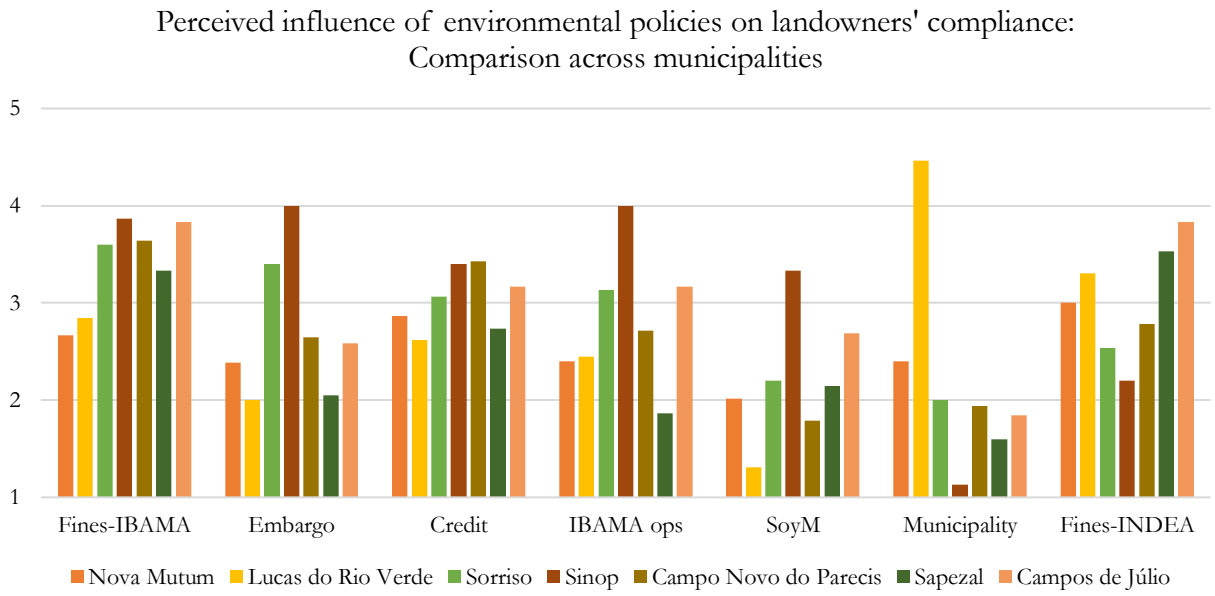


Figure 4.20. Perceived influence of environmental policies on landowners' compliance (average at the level of the municipality) broken down for each environmental policy and showing how landowner of each municipality assessed the policy on average (n= 7 municipalities; n=99 landowners). Note: Out of 99x7= 693 values, 15 were missing and were replaced by the sample average in order to complete the data.

Embargo. According to environmental laws, an embargo should be created on any property having received an environmental fine. The landowners who most acknowledged the influence of embargo on the behavioral change in their municipality were those of Sinop and Sorriso. This is consistent with the observations made about environmental fines since Sinop is fully located in the Amazon biome and deforested late while Sorriso has a good portion in this biome and the northern part of the municipality was cleared in the early 2000s. The likelihood of being detected by the

satellite monitoring was high too since these areas present more forest cover than other municipalities of this study.

Credit perception. Perceptions about the influence of credit suspension on the behavior of landowners are more balanced across municipalities than other environmental policies. The perception is highest in Sinop, which makes sense for a municipality where the risk of environmental fines could be higher because of the type of vegetation (i.e. clearing of forests more easily spotted by DETER and PRODES) and the timing of land clearing (i.e. intensive land clearing in the 2000s). The municipalities with smaller scores than Sinop were Campo Novo do Parecis, Campos de Júlio, and Sorriso. Given the overall balanced scores across municipalities for this measure, it is challenging to draw conclusions about the influence of credit suspension. Sorriso and Campos de Júlio may present high scores because of important deforestation events in the 2000s, but this would not explain why Campo Novo do Parecis share a similar level of perception. As annoying the suspension of credit can be, landowners frequently mentioned during the interviews how they could access other types of funding (through multinational, inputs resellers) or rely on self-funding. Hence, the threat of credit suspension may be less important than what is generally assumed for other areas of the Amazon where public funding plays a more important role than in the study area, where the degree of agricultural modernization is higher (e.g. access to multiple sources of funding).

IBAMA operations. Landowners were asked whether the mere perceived presence of enforcement patrols by IBAMA may have been the key factor dissuading them from clearing more land. The scores are highest for Sinop and Sorriso and consistent with those of those regarding

fines and embargos. Sinop, in particular, experienced a large IBAMA operation in the 2000s but it was targeting illegal sawmills rather than farmers clearing land illegally. Yet, this marked everyone's mind in the municipality, especially since many soybean producers in Sinop used to be loggers or managed sawmills prior to become farmers (or kept up this activity). Campos de Júlio has the 3rd highest score on this measurement. These three municipalities score highest on all measures linked to IBAMA, revealing that the combination of late deforestation (early 2000s) and location in the Amazon biome may be two of the most important determinants of perceived impact of environmental policies.

Soybean Moratorium. Several multinationals agreed in the Soybean Moratorium (SoyM) to not purchase any soybean grown on land cleared after 2008 (originally 2006 in the first version). This, quite logically, concerns more the municipalities that deforested late and that perhaps would have wanted to be able to do more. Landowners in Sinop and Campos de Júlio, two municipalities that deforested late, were the ones to acknowledge the highest influence of this initiative on the behaviors they saw locally. Yet, measures do not score as high as those related to IBAMA, suggesting that the threat may be weaker than that of environmental policies. Overall, the perception of an influence of the SoyM is low, partly because there are other traders that did not make this commitment and thus can commercialize soybean considered illegal under the SoyM (Trase 2018). As told by several landowners, it also possible to use loopholes to sell a harvest grown on such lands (by asking someone else to sell soybean on their behalf).

Municipality. Overall, municipalities in the study area barely had any role in helping soybean producers to get into compliance with the FC, at the exception of Lucas do Rio Verde (score of

4.46, the highest of all measures of environmental policies for this question). Contrary to others, the municipality of Lucas do Rio Verde was a pioneer in the compliance of landowners and adopted a pro-active approach to give landowners opportunities and means to respect the FC (Rausch 2013).

INDEA fines. Finally**,** the role of a particular agency needs to be highlighted. The INDEA (Mato Grosso's Institute for Agricultural Defense[235]) is in charge of controlling the use of chemicals and the planting calendar of farmers in the region. One of their main tasks is to control that farmers respect a "sanitary window" (the *vazio sanitario*), which refers to the prohibition to cultivate soybean as a second harvest which provide a time period where no soybean is grown in the region and can potentially provide a way for soybean-related pests to survive through a whole year. Another mission is to control the correct use and disposal of chemicals by landowners. Unlike other agencies like IBAMA or SEMA, there are typically one INDEA office per municipality. Their local implementation allows a closer monitoring and enforcement of producers, but also give such producers the opportunity to visit and consult them about any administrative procedures. Generally, the acceptability of such an agency by producers was high, also because it offers producers the possibility to denunciate potential illegal practices by their peers. The role of INDEA seems highest in four municipalities (Nova Mutum, Lucas do Rio Verde, Sapezal, and Campos de Júlio) but is uncertain why the fines imposed by INDEA score higher in these than in others. Some may be better equipped to carry out their mission than others or, as told by several producers, some local agencies have better leadership than others which increase their acceptability and subsequent impact on producers' behavior.

[235] Instituto de Defesa Agropecuária de Mato Grosso

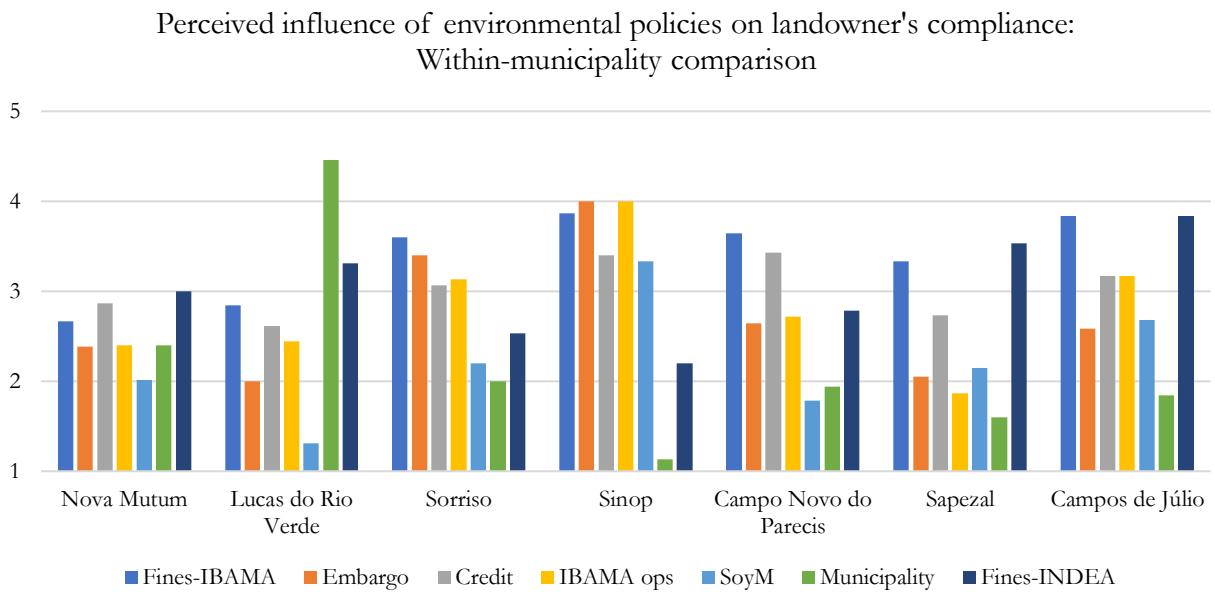


Figure 4.21. Perceived influence of environmental policies on landowners' compliance (average at the level of the municipality) broken down for each municipality and showing how different environmental policies compare within the municipality (n= 7 municipalities; n=99 landowners). Note: Out of 99x7= 693 values, 15 were missing and were replaced by the sample average in order to complete the data.

Comparing the impact of each policy within a same municipality, other patterns appear (**See Figure 4.21**). In most municipalities (i.e. Nova Mutum, Lucas do Rio Verde, Campo Novo do Parecis, Sapezal), soybean producers do not deem federal or state command-and-control measures to have had an important impact on their behavior. On the contrary, producers from Sinop seem to have perceived a higher influence of these measures on producers from their area, which may be explained for the same two reasons than above. First this perception matches with the relatively higher deforestation occurring in Sinop as compared to other study municipality in the 2000s, right at a time such policies began to be enforced in a stricter way. Second, Sinop is the only municipality of the study to be almost fully located in the Amazon biome and was clearly covered by denser forests than other municipalities. As a result, the monitoring and enforcement of environmental policies may have been higher there, consistent with some of the assumptions underlying the argument of this dissertation.

5. CONCLUSION

During interviews, most farmers in the *Cerrado* area shared their incomprehension about being perceived as deforesters or "environmental destroyers" by the Brazilian public (i.e. mostly urban) and the international community. They perceive themselves as having arrived in the Cerrado because it represented opportunities to cultivate larger areas than in their native states of Southern Brazil, pursuant to public policies incentivizing colonization of the Amazon at the time. Far from clearing most of their land area upon their arrival, they argued they opened up their properties at a steady and regular pace. Many reported clearing 50 to 100 ha per year, depending on the results from previous year harvests.

To a large extent, this version of the story is confirmed by the land-use data gathered for this study. This chapter has documented the clearing pattern of large-scale soybean producers over 30 years (1985-2015) by laying 3 hypotheses:

H1: Producers have different pace and timing of property clearing

H2: Landowners in Cerrado-located properties follow a similar progressive and constant clearing pattern and differ from those in Amazon-located properties

H3: Landowners' decisions about land clearing in Cerrado areas were limitedly by changes in economic conditions or environmental policies while those in Amazon areas were more affected by such changes.

The analysis resulted in the following observations at different analytical levels:

- **Sample-level:** As the graph of property-level land clearing shows (Graph 5.1), landowners in the Cerrado biome cleared land at a steady and declining pace within the first 20 years until stopping around 2005. On average, an area of 20% of the properties had already been cleared in 1985 reflecting the different arrival dates of colonist (some started clearing earlier). Over the entire period, farmers never crossed the minimum 20% legal reserve (LR) which was in force until 2001 but did go over the 35% LR requirement change after it was enacted in 2001. In the Amazon biome however (in Sinop) farmers followed a different trajectory because of different land-use (ranching and logging). After they started planting soybean around the mid-1990s clearing accelerated forcefully until 2005. After 2005, clearing stopped in all properties and all biomes.
- **Municipal-level**: Land clearing in Parecis was swift as the vegetation was mostly Cerrado (in less than 20 years) whereas it was more gradual in the BR-163 which presented a different mix of vegetation cover, with a higher ratio of forests as compared to Cerrado, and a longer colonization history). The analysis of municipal-level trends shows especially that fewer forests were cleared in the Chapada dos Parecis than in the BR-163, partly because properties there included more Cerrado vegetation than properties in the BR-163 (which faced a 50% Cerrado – 50% forest vegetation profile overall).
- **Biome-level FC compliance**: Properties located in both biomes do not present, on average, major differences in clearing extent. This means that properties in the Amazon biome generally disrespected old and new clearing limits established by the Forest Code (FC). Properties in the Cerrado disrespected the new limits but seem to have respected the old ones. Importantly, landowners in both biomes kept clearing despite LR changes. One important difference however: Contrary to rural properties in the Amazon biome

which had already crossed their legally authorized clearing limits when the law changed, properties in the Cerrado crossed the limit after the change was enacted.

- **Property-level**: What the analysis reveals is that all producers seem to have shared a common plan because they all cleared relatively high shares of their property, regardless of the biome or municipality. However, the date at which they plateau is different. The size and timing of the different plateaus seem to be time and size invariant, although smallest properties seem to reach their plateau more quickly.

The effect of policies to reduce deforestation is difficult to disentangle. It appears fairly clear, however, that the majority of producers did not take heed of the LR changes occurring in 1996 for forest-dominated areas and 2001 for Cerrado-dominated areas. It is unclear whether the general stalling of clearing rates in 2005 is a result of the agricultural crisis of 2004-2005 or the creation of the PPCDAm. However, two things appear in the analysis. First, in 2005, many properties had reached the LR limit or were well past it. Second, many properties had already stopped clearing before the 2000s, and present different shares of cleared area which demonstrates that producers do not necessarily stop right at the LR limit. These producers may have reached other biophysical or financial limits that forced them to switch from extensive to intensive production systems. However, given the variability of plateaus reached by properties, a hypothesis based on biophysical limits is at best incomplete. On the contrary, the fact that properties with both small and large extent of cleared land stop expanding at the same time supports the idea of changing financial conditions and production systems. The major limit of this chapter is to not analyze the compliance of rural properties with the FC based on the transition vegetation areas where the LR limit would

be 80% (50% before 2005). The reason for not proceeding to such analysis is because the RADAM vegetation classification has a coarse resolution that would result in a gross misclassification of properties in the sample into three potential categories: forest-dominated, transition-dominated, and Cerrado-dominated areas. Although the analysis is risky in terms of interpretation, one can only be surprised to see such extent of land clearing across the whole sample knowing that in many transition areas, rural properties ought to have respected higher LR limits than the one applying to Cerrado-dominated areas, especially in the BR-163 region. We can therefore speculate that an overwhelming majority of properties disrespected the limits established by the Forest Code. This may be due to a general misunderstanding of the rules (particularly blurry and instable in the case of transition areas) (Stickler et al. 2013) or this may be explained by the fact that producers did not take them into consideration when deciding what the optimal area to be cultivated should be.

The analysis of the relationship between property size and land clearing rates reveals that, overall, smaller properties tended to clear a larger share of their area than larger properties. However, this observation needs to be clearly nuanced. First, the group of large properties present the same low and high clearing extents than groups of medium and small properties. Most interestingly, the size of property tended to be correlated with the time at which producers cease to clear land (plateau). Smaller properties tend to hit plateaus earlier than larger properties, while properties over 10,000 ha almost unanimously accelerated land clearing in the period where they were not allowed to. Second, the small properties included in the sample tended to only represent 45-55% of the total landholdings of a given farmer in this category (i.e. farmers with small properties tend to own more land). It would therefore be incorrect to say that small farmers clear more land than larger

farmers. Regardless of these observations, the most striking finding is the similarity of clearing plateaus (around 70-80% of total area cleared) across all property sizes in the sample.

Some of the land-use change results are reflected in producers' perceptions of public policies to reduce deforestation it seems. Producers in municipalities that were the last to deforest extensively seem to attribute a good part of the behavioral change to fines by SEMA and IBAMA. Sinop is the outlier in all categories of policies which partly confirms the greater influence of policies there, in the Amazon biome. Similar for the Soy Moratorium which seems to be more of an annoyance in the municipalities that were the last to deforest (Sinop and Campos de Júlio).

As a result, H1 is confirmed as producers presented a wide variety of clearing plateaus (or limits). However, H2 is not fully confirmed since there are some differences in the way land clearing unfolded between the BR-163 and Chapada dos Parecis region. However, I find relatively similar clearing plateaus across municipalities and biomes (timing-wise Sinop is the last to clear native vegetation. Finally, H3 is not verified since properties in all municipalities and biomes all stopped clearing in 2005. The "hypothetical" lesser policy pressure effect in the Cerrado does not seem to be at play, but this may be trumped by the importance other factors may have played in causing land clearing to stop (market conditions, etc.).

This chapter helped answer some important questions related to producer's behavior when it comes to deforestation. Were soybean producers careful planners or opportunistic agents taking advantage of market fluctuations? The property-level analysis reveals that it is not clear at all whether land clearing rates followed market conditions opportunistically, because rates decreased

or increased in different municipalities or for different property sizes at similar time periods. It is not clear either whether producers took environmental policies into account. If most producers kept at least a 20% to 30% LR on their property, the fact that the amount of native vegetation protected does not follow a pattern linked to biomes (areas relatively more forested as opposed to areas where Cerrado vegetation predominates) is unsettling. This chapter has therefore painted a picture of soybean producers as a class that, despite differences, broadly shares the same economic plans in terms of the extent of land-use within their properties.

If Chapter 4 shows that it is difficult to disentangle the influence of different market or institutional factors on land clearing patterns, it does not address the question of how or why land clearing stopped, a topic I explore in Chapter 5.

Chapter 5. It has always been a matter of time: Both financial risks and environmental tradeoffs matter for sustainable agricultural production in the tropics

This chapter is presented under its paper version. The paper has been co-written by Martin Delaroche (lead-author), Ramon Bicudo da Silva (co-author), and Mateus Batistella (co-author). It was submitted to the journal *World Development* on Dec. 31, 2018 and is under review.

Titles and sub-titles of the paper have been adapted to fit the dissertation's style. Figures were renumbered as well.

Keywords: sustainable intensification; soybean; decision-making; Brazil; environmental policy

Abstract: In the next decades, several new areas of commodity production will likely appear to cater to the world's need for food security. Past areas of commodity production, such as in Brazil, have provided economic opportunities, but mixed social and environmental sustainability outcomes. In particular, the intensification of soybean production areas due to a set of economic and institutional conditions have resulted in land sparing, but it also generated new types of environmental impacts. In this context, it is important to understand the mechanisms behind the evolution of production strategies in this area of the world, and their associated impacts, if this model of commodity production is to be replicated elsewhere in South America or Africa. Our research questions are: (i) what are the production strategies that help explain the transition toward intensification and the ensuing land sparing?; (ii) what can we learn from the environmental and financial risk tradeoffs associated with each strategy? We combine two datasets of semi-structured interviews with producers and policy-makers in Mato Grosso (n= 103 + 31) as well as quantitative data (land-use dataset and agricultural census) to describe the evolution of agricultural practices in Mato Grosso, the leading soybean producing region of Brazil. Our study finds 5 different production strategies that differ in financial and environmental risks. Importantly, some strategies are more likely to reduce both risks than others. However, such strategies are contingent to technological, economic, and institutional conditions, and will revert if such conditions change. Public policies and zero-deforestation initiatives emphasizing intensification must therefore pay attention to the difference between intensification types if they are to promote environmental sustainability. The uptake of production practices promoting environmental sustainability in new commodity production areas will likely depend greatly on the technological, economic, and institutional context at the international level.

1. INTRODUCTION

Increasing food production and food security while ensuring environmental sustainability are interrelated challenges that may sometimes seem contradictory. While not everyone agrees, many voices have nonetheless pointed out that increasing food production will be inevitable to ensure food security for the 9 billion (bn) people that will inhabit the planet in 2050 (Nwanze 2017). In that context, new areas of commodity production are likely to appear. African savannas and dry forests regions are thought to be the world's next frontier for large-scale soybean and maize production (Gasparri et al. 2016; Sinclair et al. 2014), a strategy embraced by the African Development Bank (AfDB) (Ojebode 2017). Africa represented 12% of China's outbound agricultural investments in 2014 (Gooch and Gale 2018) and countries like Brazil – projected largest soybean producer and exporter in the world in 2018 – are directly exporting their production model there (e.g. Mozambique, Ghana, etc.) through investments in technology and infrastructure (Cabral et al. 2016; Amanor and Chichava 2016).

However, replicating the South American model of commodity production in Africa raises some concern. Despite positive economic and social contributions (Rachael D. Garrett and Rausch 2016; Martinelli et al. 2017), the expansion of these commodities in South America's ecological biomes (e.g. Amazon, Cerrado) over the past 30 years has also raised serious environmental concerns, with impacts ranging from deforestation to agrochemical overuse, especially in Brazil and Argentina (le Polain de Waroux et al. 2017; Arvor et al. 2017; P. Richards et al. 2015). In the Brazilian Amazon, the gradual intensification of soybean production systems, together with changes in market conditions and environmental policies, have mitigated some of these impacts (Macedo et al. 2012; Nepstad et al. 2014) and thus offers a window into the environmental performance of

commodity production. Given the significance of the soybean sector in regional and world environmental change, it is critical to draw lessons from soybean production areas of South America if we are to minimize the financial and environmental risks of replicating such production models in Africa or other parts of South America.

In this paper, we analyze the lessons learned from the soybean production areas of the Brazilian Amazon, focusing on Mato Grosso, which have been heralded as the "success" story of sustainable commodity production because a combination of factors resulted in production intensification and the slowdown of deforestation (Nepstad et al. 2014). Our research questions are: (i) what are the production strategies that help explain the transition toward intensification and the ensuing land sparing?; (ii) what can we learn from the environmental and financial risk tradeoffs associated with each strategy?

A consolidated literature exists at the regional-level to demonstrate whether soybean agricultural intensification helps avoiding further deforestation (Barona et al. 2010; P. Richards, Walker, and Arima 2014; Arima et al. 2011; Barretto et al. 2013; Nepstad et al. 2014), the so-called land sparing. However, much of the current work focuses at the regional-level and overlooks the important property-level financial and environmental risks involved in such a transition (Galford, Soares-Filho, and Cerri 2013; Arvor et al. 2017). Few works have documented the economic transitions of soybean producers in Mato Grosso (Campari 2005; Almeida and Campari 1995), but even fewer have addressed the production strategies they used through time to cope with such risks. More recently, Carauta et al. (2016) have analyzed the results of different crop production strategies based on the observation that producers in such areas have more and more variables to

tackle as more complex production systems emerge. However, to our knowledge, no previous works have looked at how Mato Grosso producers change production strategies over time to minimize financial risks and analyzed how these strategies have a variety of environmental impacts.

This study contributes to the current literature by offering an in-depth examination of the evolution of producers' strategies over the entire history of the soybean production areas of Mato Grosso. Using an unprecedented dataset of producers and stakeholder interviews (n=104 + 31), we identify 5 categories of production strategies that help explain intensification and land sparing at the municipal-level, patterns that are confirmed and backed up with the quantitative data available on the area. We draw attention to the diversity of production strategies existing in soybean producing areas both in space and time, and point out the significant variability in financial and environmental risks. We demonstrate that it is possible to both reduce the financial and environmental vulnerability of soybean production if some strategies are privileged. Importantly, given the changing nature of the conditions explaining the evolution of production strategies, we ask the question: is commodity expansion in the region really over? Given the particular set of conditions in which producers develop their production strategies we hypothesize that it is not unlikely to see future expansion of soybean production in Mato Grosso if technological or institutional conditions change.

This represents a valuable addition to the discussion about sustainable intensification (Pretty 2018) which points out the limits of the land-spring debate (Mertz and Mertens 2017). Our results, showing that some production strategies may well ensure soybean producers a viable financial

future while reducing environmental impacts, is a hopeful note for the sustainable intensification of this sector. This is especially critical for initiatives trying to eliminate deforestation from commodity supply chains by encouraging intensification. Since intensification often amounts to trading one environmental impact (e.g. deforestation) for another (e.g. nutrient leaching, soil erosion, chemical use), policy-makers need to be aware how it is possible to both encourage the adoption of intensified production systems and avoid the most acute environmental impacts accompanying them (Lambin et al. 2018).

The remainder of this paper is organized as follows. Section 2 provides a brief review of the literature on the land sparing and land sharing debate and highlights the need for examining the financial and environmental tradeoffs associated with producer-level production strategies to address the challenge of sustainable intensification. The study area is described in Section 3, with the necessary background about the intensification of soybean agriculture in the Brazilian Amazon. Section 4 outlines the data and methodology used for the study. Section 5 contains the results and Section 6 provides a discussion of the lessons learned about the intensification of agricultural systems in this area.

2. LITERATURE REVIEW: AGRICULTURAL INTENSIFICATION AND LAND SPARING

The deceleration of deforestation in highly productive soybean areas has raised hopes about the future transition of these areas toward forest recovery. Much of this hope is grounded in the forest transition theory (FTT) according to which agricultural frontiers go through different stages following the "progressive adjustment of agriculture to land capability, and the consequences of this adjustment in relation to forests" (Mather and Needle 1998: 117). In short, as farmers learn

about the characteristics of an area, they increasingly focus their efforts on the best soil types and abandon lower fertility ones, leaving space for recovery. Originally based on European accounts showing how, as a frontier develops, yield increases allow farmers to leave rural areas for higher-paying jobs in urban areas (Mather 1992), this idea is somewhat linked to that of an Environmental Kuznets Curve (EKC) where environmental destruction gradually slows down as an area develops and structures its economy differently (Mather, Needle, and Fairbairn 1999). However, early authors of the FTT pointed out the time lag existing between the moment expansion stops and forest recovery starts (Grainger 1995). Other authors have also pointed out how transitions in one place are dependent on cropland expansion in another (Pfaff and Walker 2010), which would explain why the shrinking of cropland areas experienced by developed countries was accompanied by the inverse trend in developing countries in the second half of the 20th century (Green et al. 2005).

Agricultural intensification is the underlying mechanism that explains a reversal of cropland expansion over forests. Defined as an increase in input use or output per hectare, intensification leads to higher yields and production volume which, if all remains constant (especially agricultural demand), leads to a lower demand for cropland (Angelsen and Kaimowitz 2001). If the intensification driven by the Green Revolution has globally led to such *land sparing*, as much more land would have been put under production otherwise (Hertel, Ramankutty, and Baldos 2014), it did not prevent cropland expansion in most countries (Rudel et al. 2009). The effect of agricultural intensification on land sparing is therefore ambiguous at best, especially since it can also lead to further cropland expansion by increasing the opportunity costs of agriculture as demonstrated in Latin America (Ceddia et al. 2014). Rather than sparing land, there are instances in which

intensification can lead to more cropland expansion, following a Jevon's paradox also called *rebound* effect (Mertz and Mertens 2017).

Given the importance of context for explaining land sparing (Rudel et al. 2009), authors have recently turned their attention to the factors influencing the degree to which land is spared in the intensification process. Intensification is less likely to result in cropland expansion when land availability is limited technically by biophysical factors or "artificially" by institutional constraints (e.g. land-use policies, protected areas) (Meyfroidt et al. 2014). When expansion is possible, high-yield commodity crops tend to expand on land previously occupied by lower-yield land-uses and to remain close to the infrastructures needed to support such intensified uses. Widespread evidence suggests that such land-uses often do not disappear but are simply displaced further away, resulting in indirect land-use changes (iLUC) that may cause deforestation effectively cancelling the "benefits" of intensification (Lambin and Meyfroidt 2011). Intensification has other implications than land sparing less debated by the literature. In particular, intensification often pairs with increased use in fertilizers and pesticides, raising concerns about human health and biodiversity losses (Fernandes et al. 2019; Sharafi et al. 2018; Ali et al. 2018; Nordgren and Charavaryamath 2018; Pretty 2018). The debate is however divided, as some authors have argued that land sparing through intensification may be more effective at meeting the global food demand while protecting biodiversity than other forms of wildlife-friendly agriculture (Green et al. 2005).

We agree with Mertz & Martens (2017) that the discussion now needs to move from this binary debate toward a more careful discussion of the pros and cons of varying degrees of intensification. There is a growing and rich literature on sustainable intensification (SI) strategies, recognizing the

adverse environmental effects of intensification in conventional agricultural systems (Pretty 2018; Rockström et al. 2017; Gurr et al. 2016). SI involves a mix of practices rather than one alternative system. It involves practices such as precision agriculture or integrated pest management (IPM) that both increase yields and significantly improve the environmental outcomes of agriculture based on monocultures. It involves different degrees of technological change: efficiency, substitution, and redesign. However, since only 4% of farms in industrialized countries rely on such techniques, SI has a long way to go in both industrialized and developing countries if it is to make a substantial contribution to the environment (Pretty 2018).

We note that the land sparing literature has seldom discussed the variety of changes in farmer production strategies (i.e. beyond simply an increase in input use or output production) explaining intensification at the landscape scale. Understanding such changes is however fundamental for designing new models of sustainable production that take advantage of the differences in financial and environmental tradeoffs existing between different intensification strategies.

3. Study Area

3.1. Agricultural intensification in the Brazilian Amazon and Cerrado areas of Mato Grosso

In the past 30 years, soybean production in Brazil grew tremendously, creating new economic opportunities but also clearing large extents of native vegetation especially in the area known as a transition between the Amazon and Cerrado ecological biomes (Martinelli et al. 2017; Rachael D. Garrett and Rausch 2016; Weinhold, Killick, and Reis 2013a). Brazil became a top producer and exporter of soybean mostly due to the state of Mato Grosso which today accounts for 30% of the

soybean production in Brazil (9% worldwide) but was virtually inexistent until the beginning of the 1980s (IBGE 2018).

The transformation in practices of Mato Grosso's soybean producers over time has been grounded in larger macroeconomic, technological, and institutional trends. It is widely recognized that the economy of the Brazilian Amazon was increasingly inserted in world markets starting in the 1990s (Nepstad, Stickler, and Almeida 2006). As a result of new telecouplings (i.e. socioeconomic and environmental interactions among coupled human and natural systems across distances; Liu et al. 2013), land clearing in the Amazon started to be increasingly driven by changes in world beef and soybean prices, and beyond this, by processes occurring in other countries such as the outbreak of bovine spongiform encephalopathy (ESB) in Europe in the 1990s or the rising meat demand in China caused by economic development and rural outmigration (Silva et al. 2017). Brazil would not have been able to face such a rising demand without the technological improvements made to soybean varieties adapted to tropical conditions and other related innovations (e.g. no till systems, double-cropping, nitrogen fixation of soybean, etc.) (Nehring 2016).

Since the 2000s, a combination of land scarcity, market factors, and strong public policies and private sector initiatives resulting in territorial constriction has created incentives for soybean producers in these areas to intensify production (Thaler 2017; Nepstad et al. 2014; Spera et al. 2014). The dramatic decrease in deforestation, starting in 2004, has been the result of an accumulation of conditions including better enforcement of environmental policies (Assunção and Rocha 2014; Assunção et al. 2013; Hargrave and Kis-Katos 2013; Börner et al. 2015) and zero-

deforestation supply chain initiatives (Gibbs et al. 2015, 2016; Buckley et al. 2018) that created institutional constraints on producers' expansion strategies. Finally, a sharp agricultural crisis caused by drops in commodity prices may have also been responsible for this decline (Assunção, Gandour, and Rocha 2015). Despite these profound changes in agricultural and institutional conditions, soybean production in Mato Grosso grew 201% passing from 8.7 million tons in 2000 to 26.2 million tons in 2016 (IBGE 2018) while yearly land clearing rates decreased 456% throughout the state over the same period (14,840 km2 in 2000 as opposed to 2,667 km2 in 2016) (Figure 6).

3.2. The land sparing debate in Mato Grosso

Whether the intensification of soybean agriculture in this area led to land sparing in the Amazon has however been subject to an intense debate. Although Morton et al. (2006) assess that early intensification in the late 1990s and early 2000s was not land sparing, at least locally, other authors point out without intensification landowners may have needed an additional 16,800km2 during the period stretching from 2000 to 2006 (Arvor et al. 2012). Intensification did result in the expansion of soybean cultivation close to infrastructures, however this impact was partly hidden by the fact that an important part of that expansion took place on former pastures (Barretto et al. 2013). There is evidence suggesting that this expansion caused indirect land-use change (iLUC) further into the Amazon (Barona et al. 2010; Arima et al. 2011), however fieldwork in the area has demonstrated that it is more complex to find evidence of causal effects at the local level (P. Richards, Walker, and Arima 2014; Spera et al. 2014).

The transformation of agricultural practices in soybean producing areas of Mato Grosso has raised concerns about their associated need for fertilizers and pesticides use (Arvor et al. 2017; Neill et al. 2013, 2017). The massive adoption of no till practices in the mid 1990s was accompanied by the implementation of double-cropping systems which increased the overall input consumption and output production. This resulted in mixed environmental impacts since the rate of nitrogen, phosphorous and potassium use increased dramatically along with pesticides use, but some gains resulted from the diminution in diesel consumption since no more machines were needed for tilling (Galford, Soares-Filho, and Cerri 2013).

The environmental impacts of soybean production vary largely depending on differences in "climate, soil type and transport means and distances for different production regions in Brazil" (Prudêncio da Silva et al. 2010: 1832). Besides this macro- and regional-scale differences in production systems, few works have explored the difference in environmental impacts within a same production region, at the producer level. The current pattern of land sparing (whatever amount of forest it spares or not) and the environmental impacts associated with intensification are reflected in the current production strategies of Mato Grosso's soybean farmers. We argue that such production strategies are more diverse than the archetype no till, double-cropping systems (Galford, Soares-Filho, and Cerri 2013) and involve widely different financial and environmental risks. Understanding how landscape-level outcomes are shaped by producer-level decisions is key to designing sustainable production pathways that will mediate the environmental costs of intensified agricultural production (Arvor et al. 2012). This is also important to assessing the financial costs behind production strategies.

4. DATA AND METHODOLOGY

This study focuses on the evolution of production strategies of soybean producers in the leading soybean producing areas of Mato Grosso (Figure 1) from the 1980s through 2016. We develop a multi-level analysis that aims at linking municipal-level trends in production intensification to property-level production strategies. The evolution of such strategies took place within a context of frontier development in which farmers from southern Brazil colonized the area and cleared the land (Jepson 2006a). Since not all municipalities were colonized at the same time, nor were colonized with the same initial objective (agriculture vs cattle-ranching), we first define groups of municipalities that experienced similar settlement patterns in time and substance. We then analyze at the municipal- and property-level the evolution of production strategies within the municipalities that historically led soybean production because they showcase the greatest diversity of production strategies to date.

4.1. MUNICIPALITY GROUPS

To identify municipal-level trends of land clearing and intensification over time in the leading soybean-producing areas of Mato Grosso, we relied on multi-stage criteria to distinguish three groups of municipalities with distinct historical contexts. First, we decided to only retain the top 40 soybean producers which together represented 83.8% of the state's production in 2016. This is to ensure that we capture the trends of the producing areas that played the greatest role in Mato Grosso's agricultural development and to exclude those that are less significant in production volume, or which only started producing recently.

Second, we combined three different indicators to allocate municipalities into three different groups that would represent (1) historical frontiers of soybean production ("Group 1"); (2) areas

that turned later to soybean production and experienced a boom in the 2000s ("Group 2"); and finally, (3) emerging areas of soybean production that experienced intense clearing in the last 15 years ("Group 3") (**See Figure 5.1**). Land clearing in Mato Grosso's colonized areas was both a result of cattle-ranching and soybean expansion, it is therefore important to define historical frontiers by criteria other than land clearing, to make sure we do not classify as historical soybean production areas municipalities that were in fact colonized mostly through cattle-ranching. We therefore ranked municipalities from 1 to 40 along three different dimensions: (a) largest area cleared by 1995 (to identify the areas colonized the earliest) ; (b) least area cleared between 1995 and 2017 (to separate areas colonized earliest from areas which experienced extensive deforestation more recently) ; and (c) municipal soybean production volume in 2000 (to distinguish areas traditionally characterized by cattle-ranching rather than soybean production). We averaged the scores obtained by municipalities along these 3 dimensions to obtain a new ranking which accurately reflects the different histories of land-use in the region (please see figures n°2 and n°3 in Annex) for an explanation of the cutoff value used to distinguish the groups of municipalities).

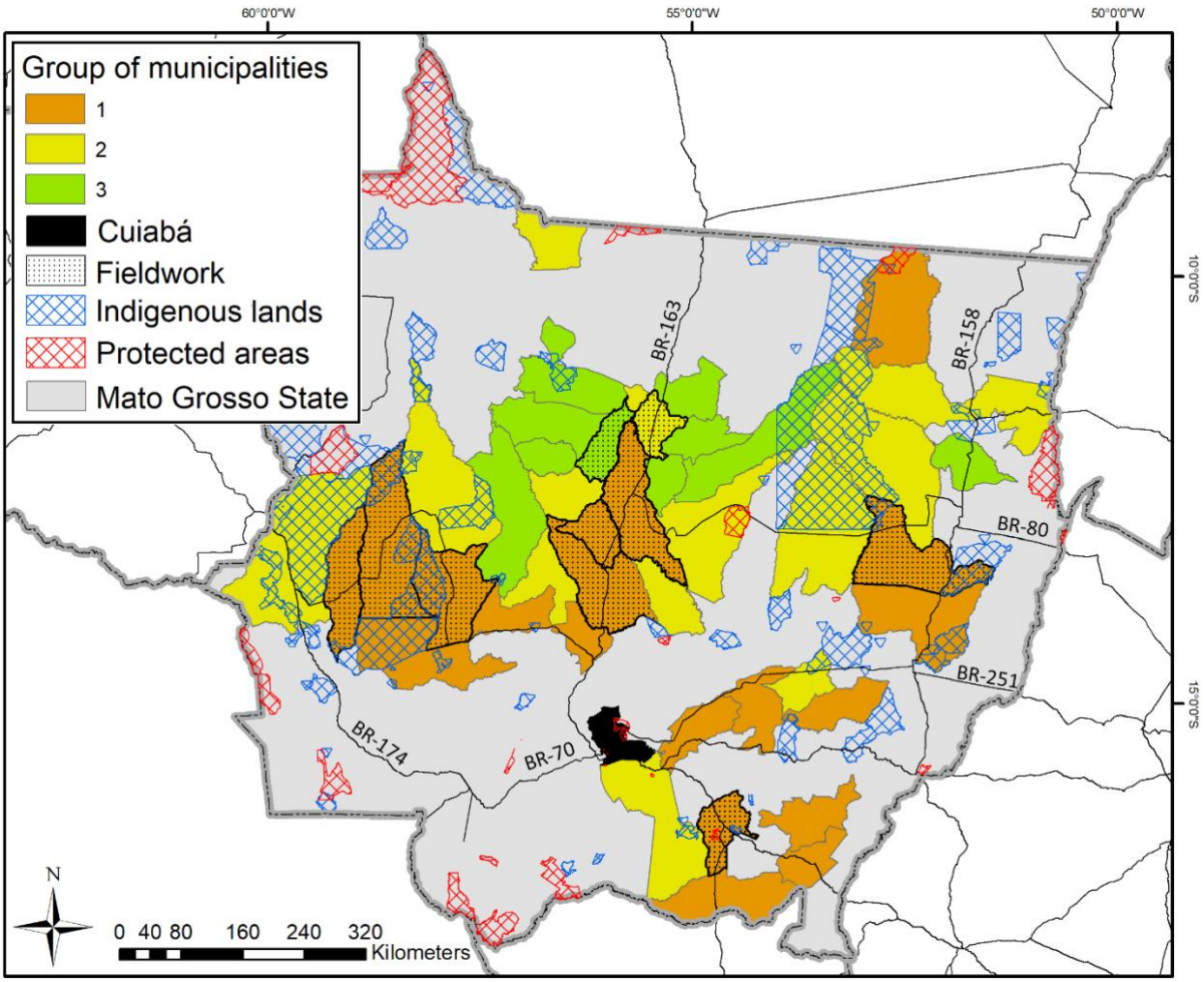


Figure 5.1. Map of the different groupings of municipalities based on frontier settlement history and soybean production. Groups: (1) historical frontiers of soybean production; (2) areas that turned later to soybean production and experienced a boom in the 2000s; and (3) emerging areas of soybean production that experienced intense clearing in the last 15 years. Please refer to Annex for detailed information about the methodology for grouping municipalities.

4.2. Property-level Qualitative Datasets

In order to understand how municipalities transition from production strategies relying on spatial expansion to those based on intensification, we mobilize property-level evidence about the shifting production strategies from two datasets with a large spatial overlap. Dataset (a) contains 104 semi-structured interviews with large-scale soybean producers (each one owning above 2,000 hectares of land) in 7 municipalities of Mato Grosso (Sorriso, Lucas do Rio Verde, Nova Mutum, Sinop, Campo Novo do Parecis, Sapezal, and Campos de Júlio) collected during extensive fieldwork

between February and July 2017 (n=104). Importantly, a subset of dataset (a) is composed of property boundaries belonging to 56 landowners which allowed us to map land-use cover change from 1985 to 2015, by 5-year periods, providing unprecedented data about the spatial implications of shifting producer strategies. Dataset (b) consists of semi-structured interviews in 8 municipalities of Mato Grosso (8) collected during fieldwork in May and June of 2017 (n=31). A description of the composition of both datasets is available in the Annex.

Importantly, the set of property-level evidence has a narrower geographical scope than the municipal-level evidence, because our argument is about the diversity of production strategies in the pioneering and leading soybean production areas of Mato Grosso, which are represented mostly (but not exclusively) by the municipalities covered by both datasets, in line with what authors have previously identified as the production "poles" of the state: the Parecis plateau region, the BR-163 highway region, the Rondonópolis area (Southeastern Mato Grosso) and finally the Querência area (Eastern Mato Grosso) (Arvor et al. 2012).

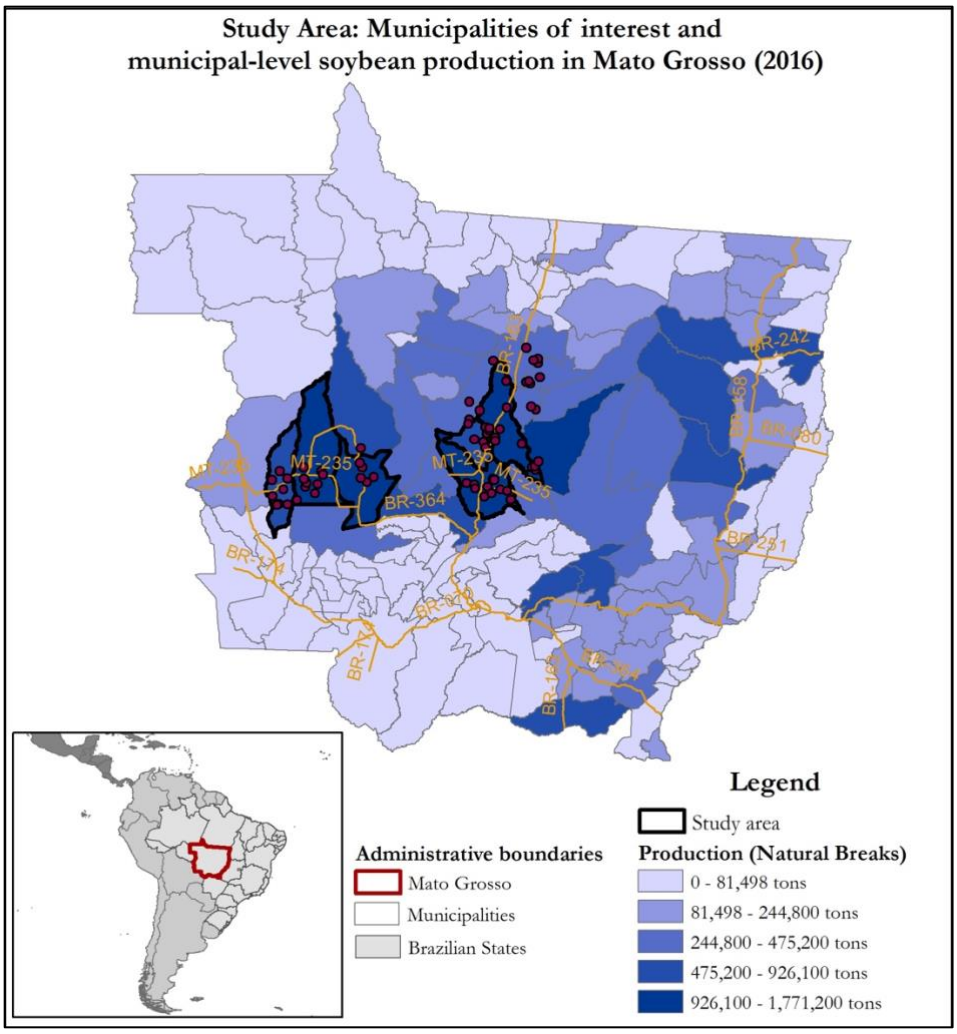


Figure 5.2. Map of the focus of interviews within the study area in Mato Grosso with dots representing the location of interviewees of dataset (a). Soybean production data from IBGE's Municipal Agricultural Production (IBGE 2018)

4.3. Soybean Production and Deforestation Data

For soybean production data, we use IBGE's Municipal Agricultural Production for crop production, planted area, and productivity (IBGE 2018). Data about land clearing since 1985 was obtained through the MapBiomas v3.0[236] dataset which allows for generating estimates about land clearing of native vegetation (forests and other vegetation types) in both the Amazon and Cerrado

[236] "MapBiomas Project - is a multi-institutional initiative to generate annual land cover and use maps using automatic classification processes applied to satellite images. The complete description of the project can be found at http://mapbiomas.org" Project MapBiomas - Collection v.3.0 of Brazilian Land Cover & Use Map Series, accessed on November 15, 2018 through the link: http://mapbiomas.org/#

biomes in which the soybean producing municipalities of Mato Grosso are located. We also use producer-level data on good agricultural practices and historical land-use change (**Please see Annex for methodology details about our classification**).

5. RESULTS

The evolution of production strategies through time was reconstituted combining both quantitative (i.e. land clearing rates, production yields at the municipal-level) and qualitative evidence (i.e. the narratives of more than a hundred producers). Following analysis of the data, we found that producers' practices could be classified into 5 main categories of production strategies over time, as the context of land scarcity and other contextual variables in municipalities evolved. Importantly, these categories do not represent categories in which groups of producers would fit neatly into one or the other at any given time. Rather, they represent a set of dominant production practices that together make economic sense, and one producer may well use practices from different production strategies at any given point in time (i.e. a producer can both intensify production and expand its production onto new areas). As a result, our argument is both grounded in time and space. However, producers do not follow a linear evolution from point A to B (e.g. expansion toward intensification), and if the conditions at the root of past strategies are restored at any point, producers may as well be tempted to turn back to older strategies. For instance, if the pressure against land expansion created by environmental conservation policies are rolled back, it is unsure whether expansion would not occur again.

5.1. EXPANSIONIST STRATEGY (1980-2000) (CATEGORY A.)

Farmers under this strategy try to reduce financial risk mainly by increasing production volume through expansion of cultivated area, rather than focusing on productivity gains on the area currently under cultivation. This strategy is typical of the early stages of the agricultural frontier in Mato Grosso, when farmers needed to clear large extents of native vegetation in order to occupy space and produce crops. The emphasis on expansion leads farmer to devote little attention to the subtle differences in soil quality existing on their property, foregoing opportunities for improving crop productivity and explaining the low soybean productivity experienced in areas where farmers opt for this strategy.[237]

When smallholder farmers from Southern Brazil arrived in Mato Grosso, in the late 1970s, they started clearing areas of Cerrado vegetation to plant rice. They did this up to 1982-1983 when they started to plant new soybean cultivars adapted to tropical climates and acidic soils, which combined with soil correction techniques based on lime (to diminish soil acidity) made soybean cultivation profitable in such areas (Souza and Lobato 1996; Queiroz, Goedert, and Ramos 2004; Gomes and Kaster 2000). In the early stages of soybean production in the BR-163 highway and Chapada dos Parecis region, farmers would be able to produce about 35 to 40 soybean bags (one bag is 60 kg) per hectare (**Figure 5.5**). In spite of the logistical challenges associated with the absence of infrastructures (which raised production costs), there were no major pest threats to soybean agriculture. As a popular saying of the time exemplified it, one could "plant and go to the

[237] The pace of clearing was significantly influenced by the type of biomass present on the property. In areas dominated by Cerrado vegetation, producers cleared land by using a simple steel cable extended between two tractors advancing parallel to each other. In denser vegetation areas, typical of Amazon vegetation, farmers may have either used a larger and heavier cable (called correntão) or used pneumatic tractors to take down larger trees. In both cases, they needed to burn what had been cut down, explaining the reliance on slash-and-burn techniques during the dry season.

beach" until soybean was ready for harvest – the nearest beach from Cuiabá state's capital is1,360 km in linear distance. This period stretching from the 1980s throughout the 1990s was characterized by intense and steady deforestation since producers privileged the expansion of area under cultivation rather than increasing productivity (**Figure 5.7**). Such an expansion took place within the property but also outside, through purchases of additional land.

The combination of low soybean productivity and cheap land price (due to land availability) made this expansionist strategy all the more attractive for producers. Agricultural activities were taxed at very low rates, some expenses were tax exempted (e.g. machines and inputs), and agricultural credit was somewhat available (Mahar 1979; Binswanger 1991). Furthermore, the 1980s were characterized by very high inflation rates as Brazil was going through a long economic crisis nicknamed the "lost decade." As a result, expanding by purchasing new land was the privileged way to reduce financial risk, since any profits not re-invested quickly could vanish due to inflation.

The lack of attention on productivity however made farming operations financially vulnerable. Any drought, or rather the excess of rain (which is the main risk in Mato Grosso) could destabilize farm operations and cause the loss of a significant portion of the harvest. This vulnerability was explained in part by the fact that producers planted soybean relying on tilling techniques inherited from their families' agricultural traditions.[238] As a way to remedy to these risks and low productivity, producers started to attempt no till methods toward the end of the 1980s but with

[238] Most colonizers of Mato Grosso came from smallholder families of Southern Brazil, who themselves had emigrated from Europe a few generations back. Their agricultural practices were thus significantly influenced by their European background, which explains that agriculture in Southern Brazil originally relied on tilling methods employed in temperate climates. As a result, their sons were doing the same thing in Mato Grosso once they arrived in the region.

little success. In the early 1990s to the mid 1990s, they started planting millet as a cover crop after the soybean harvest, but this did not generate enough biomass to guarantee the functioning of no till systems and they ended up exhausting soils.

5.2. PROPERTY-LEVEL INTENSIFICATION STRATEGY (1990-2005) (CATEGORY B.)

Once the limits of expansion onto the most fertile soils available on their property were reached, farmers started concentrating their efforts on getting better crop yields out of their planted area. Despite important productivity increases thanks to the adoption of better soybean varieties and the use of chemical inputs over the past period (A.), farmers still experienced soil fertility losses due to tilling techniques, which put them at increased financial risk. In addition, the rising land prices resulting from a stabilized Brazilian economy and the rising production costs created incentives for them to better control the overall costs associated with their activity. This resulted in the intensification of production at the property-level.

It is around this time (mid-1990s) that farmers started relying on *no till* methods to avoid soil erosion and restore soil fertility, a practice said to be the "salvation" of the region [ITW n°032]. The *no till* system theoretically relies on three principles: (1) no tilling of the soil; (2) crop (or straw) cover in between harvests; and (3) crop rotation.[239] At first, this system mostly failed because of a lack of biomass cover during the interseason, the soybean husk left after the harvest not being sufficient to provide for a good cover. In addition, they used planting machines used in rice for direct seeding of soybean which were not efficient. Farmers finally implemented the

[239] This last aspect is rarely practiced in Mato Grosso, resulting in a no till technique that mostly relies on the first two aspects.

system at large in the mid-1990s only when they started combining soybean cultivation with a second harvest (called *safrinha*) of maize. This double-cropping system provided the biomass necessary to cover the soils during the interseason and helped mitigate soil erosion and soil fertility loss while decreasing costs associated with the use of diesel by machineries in the tilling process, now abandoned.

No till systems significantly reduced both financial and environmental risks within the property. In particular, the system helped increase the quantity of carbon and nitrogen retained in the soils as well as the soil's "water-holding capacity as well as nutrient- and water-efficiencies of the crop" (Galford, Soares-Filho, and Cerri 2013: 2). This system allowed for significant productivity gains in soybean cultivation throughout the 1990s and 2000s, and reduced the financial vulnerability of farmers. It reduced the need for fertilizers, but also helped farmers save on gasoline costs (which they used for machines tilling the soil) by reducing "about 60 per cent in fossil fuels (diesel) consumption owing to the reduced use of machinery" (Galford, Soares-Filho, and Cerri 2013: 2).

Although often described as rapid (e.g. Arvor et al. 2017), the adoption of no till systems actually extended over more than 20 years even in the leading soybean-producing areas, as the data from interviews demonstrate (**Figure 5.3**), which may explain why the productivity gains have been spread out across an extended period. Vanwey et al. (2013) reported that double cropping progressed from 38.8% of the area cultivated in 2000-2001 to 62.4% in 2010-2011 (while the agricultural area almost doubled from 38,850 km^2 to 69,421 km^2 within the same period).

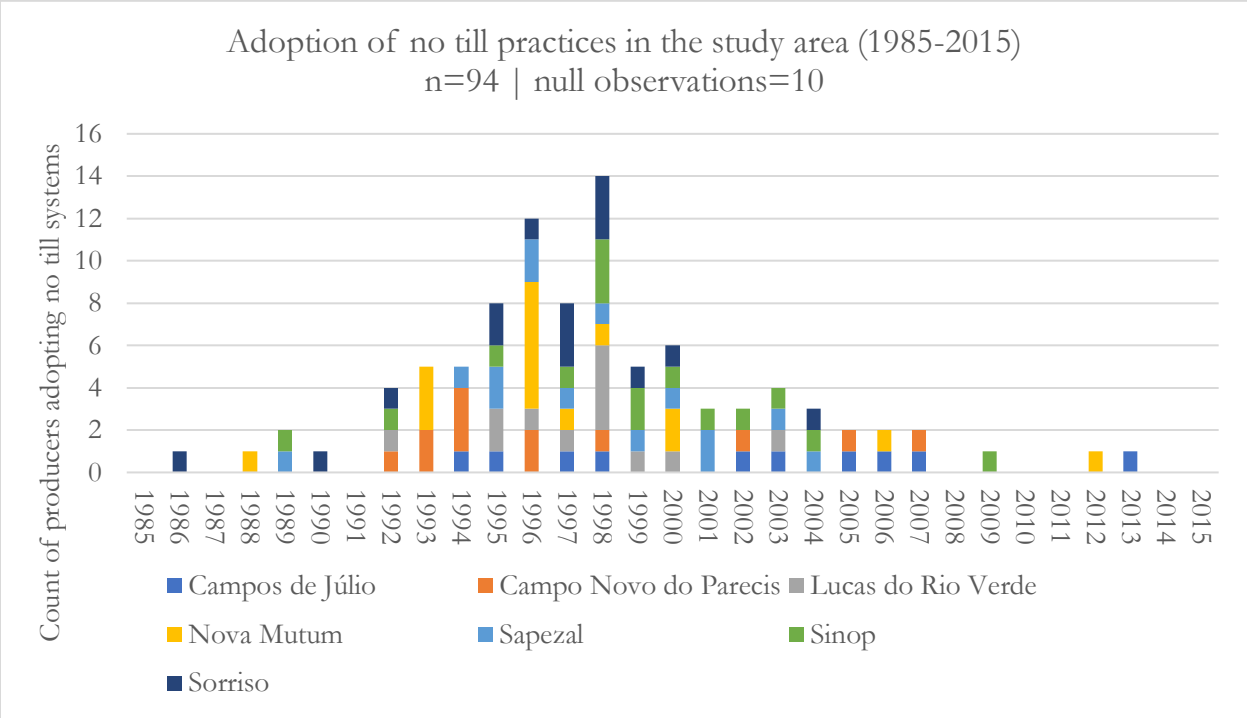


Figure 5.3. Self-reported adoption date of no till systems by producers interviewed in dataset (a) and classified by municipality of interview (n=94, 10 non-reported).

However, the improvements in productivity came with new financial risks emerging with double-cropping. Since two crops had to be planted during the rainy season, farmers were forced to work with tighter and earlier planting windows for soybeans to make room for maize earlier in the agricultural calendar. This schedule allowed maize to receive a greater quantity of rainfall before the rainy season's end. At the beginning, producers lost a significant amount of the maize because crop varieties were not adapted to short harvest season and thus could significantly suffer from drought. Double-cropping systems also resulted in the stagnation of soybean yields caused by the adoption of short-cycle soybean varieties (with lower yields) to allow for the earliest planting window possible for maize (CONAB 2017). As a system of two crops, the financial risks of cultivating maize after soybeans are associated with the growing season of the second crop, usually starting in February (in Mato Grosso) (Silva et al. 2017). According to the authors, maize growing in February tends to be more exposed to climatic events such as rainfall shortages or simply an

earlier end to the rainy season, which results in a maize productivity below a producers' expectations (according to the production costs that producers invested during the planting season) leading them to accumulate larger financial damages.

These shifts in practices at the property level also had mixed environmental implications at the landscape-level (e.g. municipal level). This first turn toward intensification was not so much land sparing at least up to 2005 in the BR-163 highway and Chapada dos Parecis region (Morton, DeFries, Shimabukuro, Anderson, Arai, Espirito-Santo, et al. 2006). Although some municipalities had stopped clearing new areas by 2000 others kept up at a significant pace until 2005. This may be due to the fact that the 2000-2005 period was characterized by a combination of favorable factors to soybean agriculture (including the "overheating" of commodity markets) resulting in a record direct conversion of forests to soybean fields (Gibbs et al. 2015; Morton, DeFries, Shimabukuro, Anderson, Arai, Espirito-Santo, et al. 2006). In addition, the use of agrochemicals started to rise significantly as the quantity of crops produced per hectare within a year also increased (Arvor et al. 2017). Agrochemicals use also increased in response to the appearance of soil diseases toward the end of the 1990s (e.g. nematodes) and the appearance of the Asian soybean rust around 2002 which increased the need for fungicides (**figures 5.4 and 5.5**).

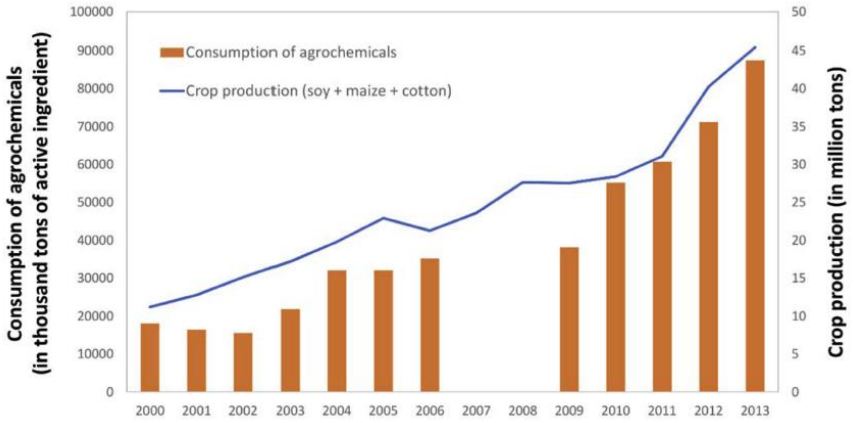


Figure 5.4. Comparative increase in soybean, maize, and cotton production with the increase in agrochemical consumption at the state-level in Mato Grosso (Source: Arvor et al. 2017).

Difference of production strategies between municipality groups

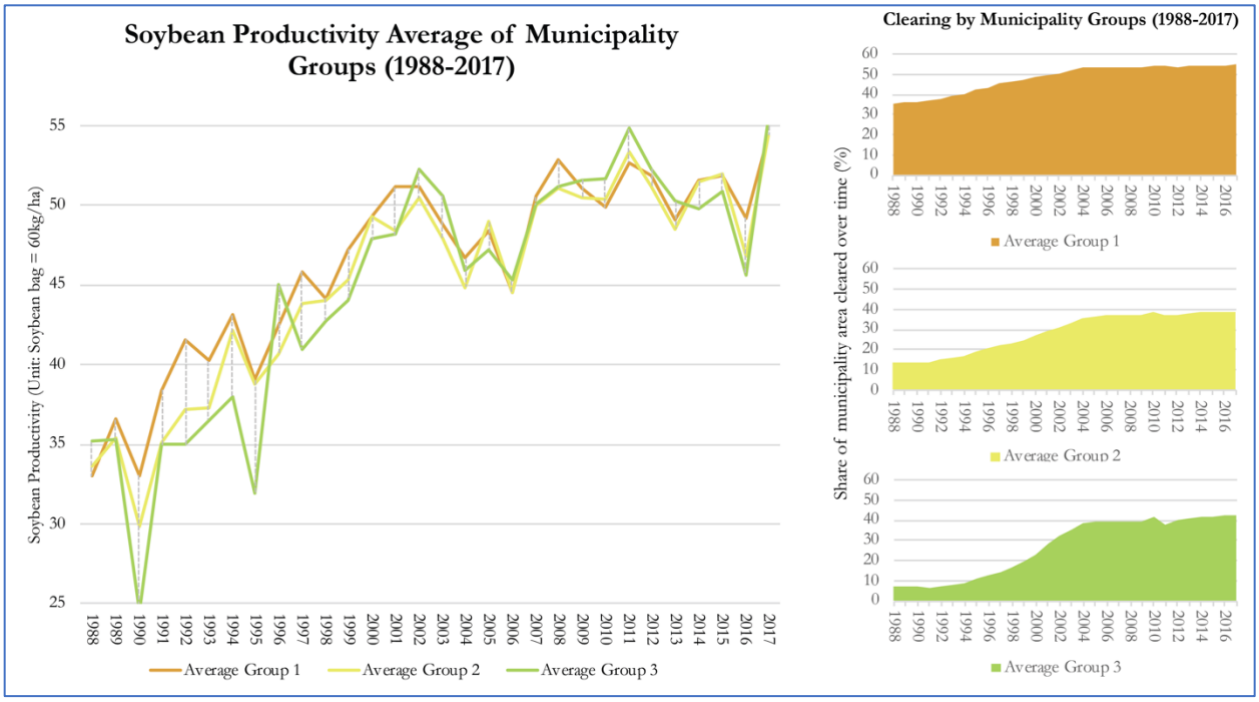


Figure 5.5. Comparison between the average soybean productivity (in numbers of soybean bags: 60 kilograms per hectare per year) and average land clearing rates (in percentage of total municipality area cleared per year) between group 1 (n=18), group 2 (n=12), and group 3 (n=10) municipalities. **Data: (1)** Productivity data from IBGE's Municipality Agricultural Production; **(2)** Land clearing averages data based on the MapBiomas v3.0 dataset. **Note**: Land clearing averages were generated based on the land transition matrices of the MapBiomas v3.0. Land clearing from one period to the other was interpreted as any land cover change from level-1 land classes n°1 (forest) and n°2 (non-forest natural vegetation) to level-1 land classes n°3 (agriculture & cattle-ranching), n°4 (non-vegetation area), n°5 (water), and n°6 (non-observed).

The turn toward intensification-based production strategies occurred at different times depending on the degree of area cleared (i.e. remaining area available) in each municipality. In the 1990s,

producers in the municipalities of Group 1 were gradually entering a period of frontier consolidation and intensifying production, while producers in Group 2 and Group 3 municipalities around them were expanding and heavily clearing forests (groups 2 and 3) (**Figure 5.5**). This is quite logical since Group 2 and Group 3 municipalities represent the geographical extension of the frontier which started expanding from Group 1 municipalities. Arvor et al. (2012) reported based on remote sensing analysis that a municipality like Lucas do Rio Verde (Group 1) had 50 to 90% of its area passing under double-cropping between the 2000-2001 and 2005-2006 agricultural years[240] while Querência (Group 3) stalled at 1% over the same period. Although the presence of double-cropping systems is partly explained by differences in rainfall patterns (it is more difficult to rely on double-cropping techniques in areas east of the Xingu basin) (S. Debortoli et al. 2015), Querência nonetheless held the 7th ranking of largest soybean producer (in tons) in the state in 2016 as opposed to 9th for Lucas do Rio Verde.[241] This means that after a "slow start" at the end of the 1990s, municipalities in Group 3 were able to catch up in both production and productivity the municipalities from Group 1 in the 2010s.

Figure 5.5 demonstrates how the gap in soybean productivity and deforestation rates between municipality groups until 2002 reflected differences in production strategies. The figure shows the evolution of productivity averages per municipality, which is the total production per total area in hectares. If a municipality is going through an extension phase, it means that hundreds of producers are clearing land During this phase, farmers dedicate resources both to land clearing and planting on the first cleared plots. Farmers plant rice for the first two or three years and add lime to correct

[240] An agricultural year in Mato Grosso begins in July ending in June of the next year

[241] Although the two municipalities are dissimilar in size as Querência is much larger than Lucas do Rio Verde, the soybean planted area of the former was 330,000 ha and that of the latter was 237,000 ha.

soil acidity with a view to get soils ready for soybean cultivation. Land plots require several years before they are able to deliver higher yields. As a result of this and the fact that farmers dedicate relatively less attention to such plots when they are still looking to expand cultivated area pushes down the yields in such municipalities as compared to what can be observed in consolidated areas where farmers had time to work on improving soil performance for years. These municipalities, less characterized by deforestation since most fertile soils have been cleared, are logically characterized by higher yields.

In summary, as one can observe on the curve of productivity gains (**Figure 5.5**), the focus on property-level optimization help explain how producers in the study area went from producing 35 soybean bags per hectare in the 1990s to around 50 in the 2000s. However, the adoption of no till and double-cropping systems (that make one) also created new risks, among which is the stagnation of soybean yields caused by the need for short-cycle soybean varieties in order to accommodate for the second harvest of maize which led to "sacrificing" long-term soybean productivity to make no till systems work (CONAB 2017). Our interviews have revealed that the adoption of double-cropping systems were less about producing maize than allowing no till systems to function in Mato Grosso. At the turn of 2000s, the maize harvest was still called "little harvest" (*safrinha*) instead of now "second harvest" (*segunda safra*) which denotes how farmers planted maize with no intention of taking advantage of commodity trading. The intention was still to boost soybean production, which explains why the adoption of no till systems did not result in intensification immediately and one can observe expansionist behaviors over the 2000-2005 period (Sorriso and Sinop are good examples of this), confirming Morton et al.'s (2006) results showing that intensification was not land sparing until at least 2005. With time however, soybean producers

started optimizing the double-cropping systems to increase farm's total production and the profit margins of their operation.

Although this period helped reduce financial risk, it is a little unclear whether it helped reduce environmental harm since there was no discernable effect on deforestation rates. What is more, this period was characterized by a significant increase in agrochemical use to cater to the increase in production in both soybean and maize.

5.3. PLOT-LEVEL INTENSIFICATION STRATEGY (2005 ONWARDS) (CATEGORY C.)

Given the impossibility of increasing production through expansion on new areas in a consolidated frontier (A.), and the productivity limits associated to a model based on property-level cost reduction (B.), farmers started focusing on increasing the per-hectare profitability of their farm. In such a strategy, farmers look at their property as a collection of land plots with varying physical and soil fertility characteristics. In areas where soils are poor and require a large amount of inputs to improve, it is uncertain whether large investments in soil fertility would be worth the costs since production gains might be small. On the contrary, in areas of higher soil fertility, little investment can lead to disproportionately higher crop productivity and benefits. Farmers can rely on precision agriculture[242] (which helps them gather plot-by-plot soil information before using adequate machinery to distribute inputs based on soil characteristics and planned

[242] A definition of precision agriculture is provided by Pretty: "Precision farming requires sensors, detailed soil mapping, drone mapping, scouting for pests, weather and satellite data, information technology, robotics, improved diagnostics, and delivery systems to ensure that targeted inputs (such as pesticide, fertilizer, and water) are applied at an appropriate rate and time to the right place only when needed" (Pretty 2018: 1).

investments) to optimize their investment in crop production for each plot, maximizing savings and benefits at the overall property-level.

In 2004 and 2005, the combined effects of a soybean price drop, exchange rate drop (i.e., devaluation of the Brazilian Real against the US Dollar) and a major drought caused a major agricultural crisis in Mato Grosso (**Figure 5.6**). The "euphoria" of the early 2000s[243] which translated to cropland expansion was replaced by farm bankruptcy and a cascade of highly-indebted producers (Andréa Aguiar Azevedo 2009). In combination with this, in 2004 the federal government passed several environmental policies to tackle illegal deforestation, which resulted in a sharp deforestation drop in the years following (further reinforced in 2008) (Nepstad et al. 2014). Finally, soybean exporters established a moratorium on deforestation after 2006, agreeing not to purchase any soybean grown on areas directly converted from forests (ABIOVE 2018; Dou et al. 2018). Faced with such unprecedented constraints in terms of land expansion, both within (since most suitable areas had been cleared) and outside (further expansion being subject to authorization) their property, soybean producers started realizing that more gains may result from optimizing production at the plot-level[244] instead of just intensifying at the property-level with the hopes to expand further.

[243] A combination of high soybean price, advantageous exchange rate for soybean exportations, and important availability of rural credit

[244] By "plot" we mean here the unit used in precision agriculture and referred to in Portuguese as "talhão." This unit describes an area with homogenous soil and topographic characteristics. Based on indicators averaged at this level, producers decide how much fertilizer, nutrients and pesticides to allocate. In large-scale soybean and maize agriculture, this unit can vary between 10 hectares to 100 hectares or more. (https://www.ibm.com/developerworks/community/blogs/tlcbr/entry/precisao_na_agricultura?lang=en)

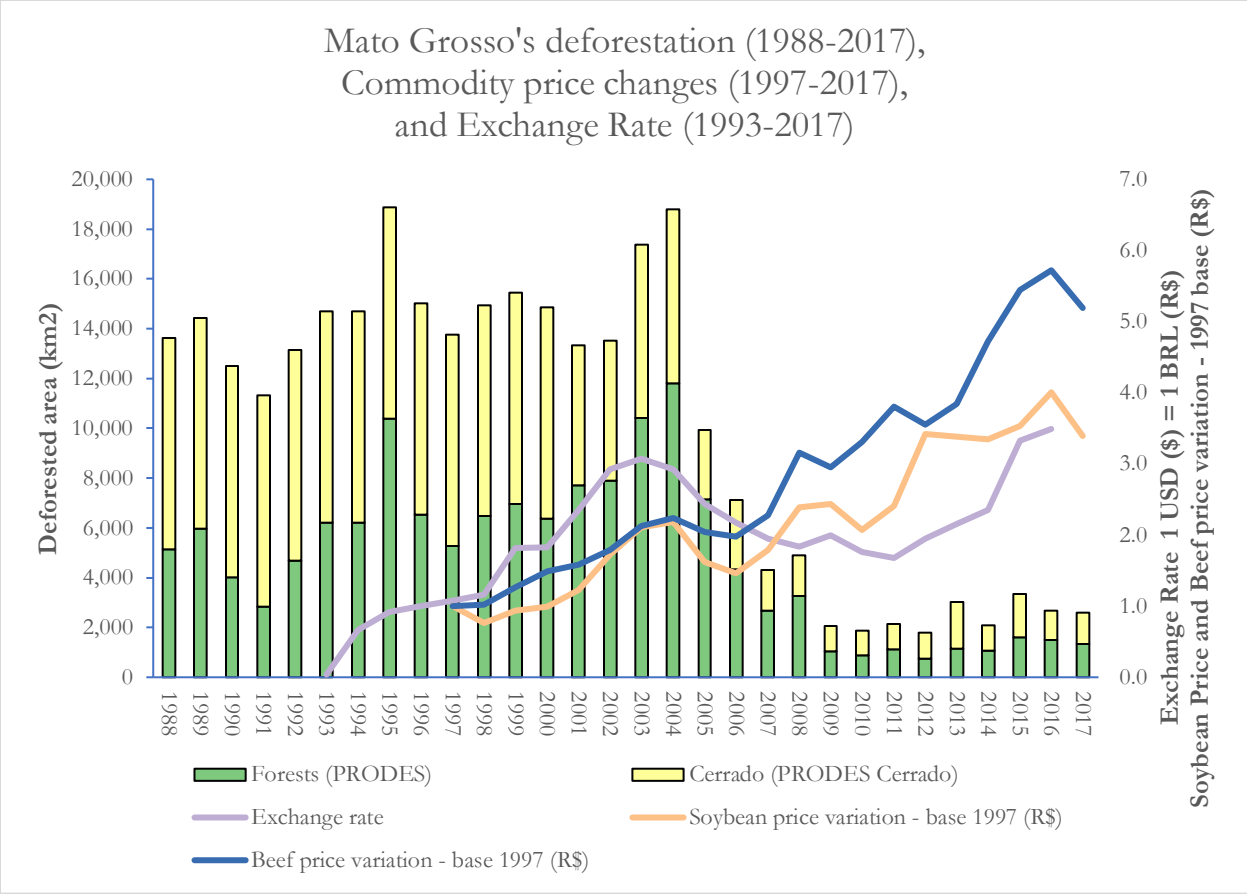


Figure 5.6. Deforestation rates in the state of Mato Grosso (in square kilometers) between 1988 and 2017 **Data**: deforestation rates based on PRODES data (for the Amazon biome) (INPE 2018a) and PRODES Cerrado (for the Cerrado biome) (INPE 2018b). Exchange rate between $1 (USD) and R$ (BRL) based on World Bank data. Variation base 1997 of soybean export prices at the port of Paranaguá (in the state of Paraná) and beef prices (R$) based on CEPEA-ESALQ data. **Note**: Since no data were available about Cerrado clearing before 2000, the initial mapped area of cleared Cerrado first available for 2000 has been divided for all the years before 2000 back to 1988 to facilitate the comparison with the PRODES data.

Switching to a per-hectare (or plot-level) optimization model holds several implications for financial and environmental risks. First, since the focus is on higher profitability, the focus on productivity only makes sense insofar as it lowers financial risk. At least theoretically, the same economic margin can be achieved by either a low-inputs/low-productivity strategy or high-inputs/high-productivity strategy, since what matters is not the level of costs and benefits, but the size of the spread between these costs and benefits. As a corollary of financial risk reduction strategies, the environmental impact may be much lower when a farmer uses a low-inputs/low-

productivity strategy as compared to a high-inputs/high-productivity strategy since the amount of agrochemical input needed in the former strategy is much lower than in the latter.

Second, since the general orientation of this strategy is to reduce costs, the objective of the farmer is to get away from the dependency from input providers since this is one of the best ways to reduce costs. We observed through our interviews that producers achieved this goal through a variety of practices. Producers started using fewer chemical inputs (as it means fewer costs) and increasingly purchased biological fertilizers or produce them on the farm. They also reported using biological pest control techniques that have less environmental impact than their conventional counterpart. Some had even started the on-farm production of seeds to avoid the increasing costs linked to new GMO varieties released on the market by multinationals, thus avoiding technological treadmills – which make producers reliant on input supply companies (Röling 2009; Gutierrez et al. 2015; Chatalova et al. 2016). Third, since precision agriculture production techniques require more work and control at the plot-level, the size of the area a producer can focus on is significantly smaller than under property-level intensification strategies. Hence, the demand for expansion on new land logically declines since expanding would result in less resources allocated per plot, if all else equals.

As **Figure 5.6** demonstrates, this property-level to plot-level shift in production strategies contributed to soybean farmers of Mato Grosso to keep increasing production and responding to market signals without causing much further deforestation. Our field interviews and data further provide evidence to support this point. In dataset (a), the boundaries of the properties of 56 landowners were obtained and land clearing pattern over 1985-2015 analyzed. The analysis

demonstrated that all soybean-producers included in this analysis stopped any significant land clearing after 2005 (**Figure 5.7**). **Figure 5.5** shows that this property-level trend also occurred at the municipal-level since all municipality groups drastically reduced or stopped altogether clearing land past 2005.

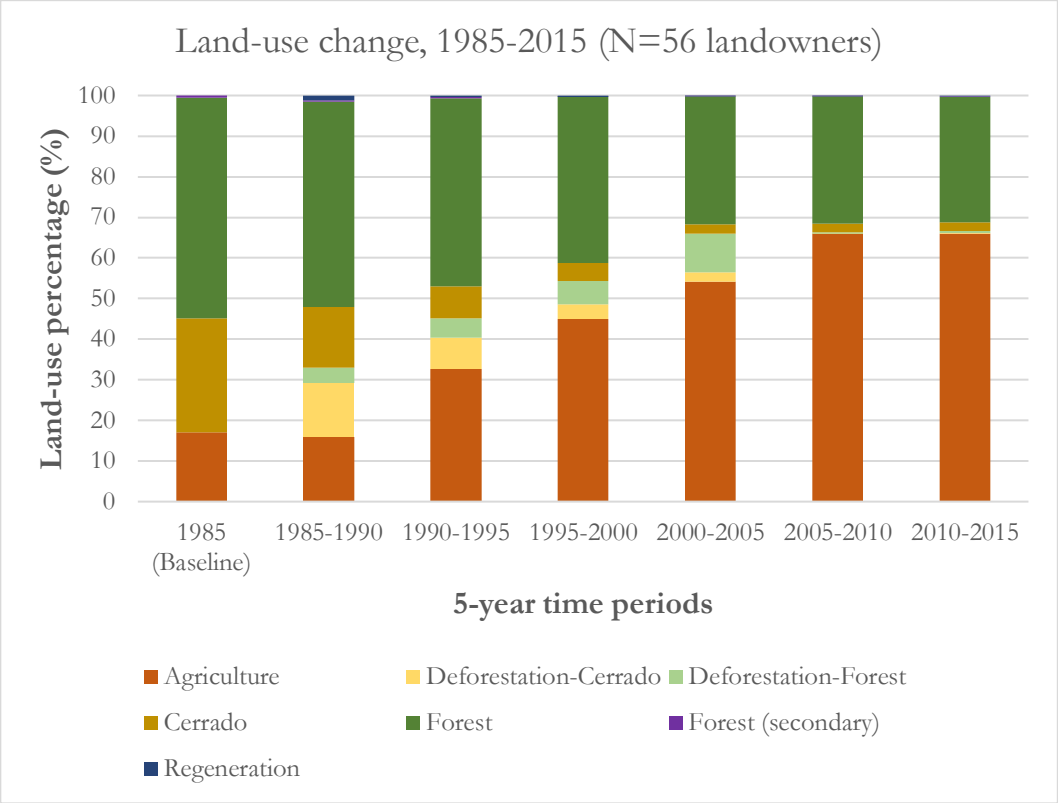


Figure 5.7. Land-use change in terms of area percentage of the surveyed properties (N= 65) for the landowners in the sample (N=56) in both the *Cerrado* and *Amazon* biome. The agricultural area passes from 15.9% to 66% of the total property area, on average across the sample. Total land area covered by the sample: 324,692 hectares (ha).

5.4. COMMERCIALIZATION STRATEGY (2000 ONWARDS) (CATEGORY D.)

In order to cope with the price instability characterizing commodity markets, farmers gradually developed better crop commercialization strategies to reduce their financial vulnerability. The focus of this strategy is to, all else equals, obtain better price conditions. Farmers concentrated on both input (e.g. fertilizers, insecticides) and output prices (e.g. soybean production). Various sets of practices can be used to achieve these objectives, including joining farmers' cooperatives,

making bulk purchases with a group of farmers, selling production under futures contracts (i.e. at a fixed price at a determined period in advance), and participating in "green" certification schemes (e.g. premium prices).

This group of strategies distinguishes itself from the others by the fact that any practice changes influence the financial risk of farm operations without changing the impact on land-use, thus they are often described by producers as the "from the farm gate to outside"[245] aspects of farm management. These aspects are critical since two farms may have the same production performance, but one may be financially unviable because the sale of production output is not well-negotiated on markets. As a result, we infer from this that farms could potentially both be less financially vulnerable and have a smaller environmental footprint if the appropriate strategies were followed.

Occurring alongside the changes in property-level and plot-level production strategies, producers in Mato Grosso started better organizing the commercialization of their crops. This aspect was particularly reinforced after the 2004-2005 soybean crisis in Mato Grosso, during which most producers suffered the impact of price fluctuation. A tool previously restricted to the wealthier producers, public credit, permitted producers of various sizes to invest in crop storage facilities and crop drying equipment. Crop on-farm storage facilities allowed farmers to hold off on selling crops whenever the price was too low and wait for a few months for a price rise in order to do so. The use of crop drying facilities increased too since one consequence of double-cropping systems

[245] Producers refer to the "from the farmgate to outside" ("da porteira para fora") as all the activities relating to commercialization of their crop and not concerning the internal management of the farm production, as opposed to the "from the farmgate to within" ("da porteira para dentro") which refers to production practices.

was to advance the soybean harvest date in the agricultural calendar, forcing farmers to harvest crops during a period marked by heavy rain events, increasing water content in the grain. Harvesting soybeans at the appropriate time or even earlier than the date at which the grain reaches the humidity index demanded by the market became thus critical to help farmers avoid crop loss. By the same token, harvesting earlier helped them to plant their second crop earlier too. Dryers represented a key advantage since it allowed farmer to harvest soybean at greater humidity index as compared to someone not equipped with this.

On the input side, many soybean producers increasingly got together in "purchasing groups" ("*grupo de compras*") and cooperativesto avoid dependency or unequal bargaining relations with inputs resellers or multinationals. In the 1990s, their level of indebtedness and the lack of public funding for agriculture made them dependent on such resellers for all their inputs but also for funding their harvest. When rural credit was available, it is possible that they could not access credit for other reasons (e.g. indebtedness, illegal activity). The provision of inputs by private parties rested upon bargaining inputs against a share of the future harvest. The "interest rate" from such bargain is usually higher from those offered by banks, which disadvantages farmers. As a result, groups of producers formed associations to make bulk purchases and get a better bargaining price due to the sheer volume of inputs purchased. In several municipalities of the study area, producers are also organized into cooperatives. Sorriso has several cooperatives today, including the COACEN (created in 2005) that already owns 48 storage units with a capacity to store 901,000 tons of soybean. It claims to control as much as 30% of Sorriso's production and help producers

to negotiate better prices for agrochemical inputs, provide storage capacity, and sell their production at the right moment.[246]

Producers now monitor day-to-day price fluctuations at the Chicago Board of Trade / Chicago Mercantile Exchange (CBOT/CME), U.S. Dollar-Brazilian Real exchange rates, and forecasts about commodity prices thanks to applications on their smartphone. They hire the services of consulting firms both in Brazil and the United States to monitor prices and negotiate their production on the spot or with future and options contracts. Selling future harvests (in one or two years) at a fixed price using futures contract is a strategy officially supported by the soybean growers association (Aprosoja-MT and IMEA 2015). Selling at a better price also involves environmental and social certification programs such as the Roundtable for Responsible Soy (RTRS). Soybean purchasers buying RTRS-certified soybean recognize the efforts made by producers in these areas by purchasing soybean at a premium price. Finally, producers in Mato Grosso have been planting conventional soybean (as opposed to genetically-modified varieties) in order to access European markets (which prohibit the importation of GMOs).

A variety of commercialization strategies are available for producers to reduce financial vulnerability without impacting land-use. Although the impact of some strategies (such as certification schemes) has been limited (Kuepper, Steinweg, and Drennen 2017; Lernoud et al. 2017),[247] it nonetheless demonstrates that producers do not have to lead a race toward hyperproduction necessarily detrimental to the environment (i.e. due to the need for increased chemical input use, and pressure on new areas of production). It is possible to reduce financial risk

[246] Find the source of the numbers presented here: https://www.youtube.com/watch?v=kTu5thVMIGk&t=4s
[247] The area of soybean certified by RTRS in Brazil was 431,238 ha in 2011 (Lernoud et al. 2017)

(and environmental risk), granted producers take up some of the commercialization practices that have been detailed here.

5.5. PLOT-LEVEL DIVERSIFICATION STRATEGY (2005 ONWARDS) (CATEGORY E.)

More recently, starting around the mid 2000s, producers started new crop production strategies due to riskier production conditions due to the combination of market conditions, soil exhaustion, governmental and non-governmental efforts to reduce deforestation, and the appearance of new pests (soybean rust, etc.). Producers in this category are shifting their focus away from short-term production horizons (year to year) to extend economic considerations to the medium- and long-term, considering the intertemporal opportunity costs of harvests. Producers have begun to recognize that the declining soil fertility they experienced was linked to their intensive and chemicals-heavy production practices and that they may do a disservice to themselves in the long run. Furthermore, the ever-rising production costs is making it more challenging to remain in the business.

In particular, they realized that investing and restoring soil fertility in particular plots should be the top priority. Producers using diversification strategies see their properties as a collection of land plots with varying degrees of fertility. Since they have large properties (mean property size of 4,952 ha for producers of dataset (a)), they decide to stop production and restore fertility on some plots for one or two years while leaving the others under production. As a result, producers keep producing soybean every year at a smaller scale, and rotate cultivation on plots after they have experienced one or two years out of production. This reduces financial risk by boosting production per area and lowering production costs. Contrary to regular plot-level intensification

methods described in C., farmers consider the difference in plot fertility not across space (different plots within the same year) but across time (i.e. the potential of a same plot for multiple years). There are multiple benefits to such a production system. By relying on diversification, farmers (1) avoid the current costs associated with producing; (2) optimize the intertemporal financial risk of the farm; and (3) build up the resilience of their soils to extreme weather events (e.g. droughts or rain over abundance).

To achieve soil fertility improvements, producers hire the services of microbiologists to analyze soil structure and health, and plant a variety of cover crops (instead of just maize) during the interseason to minimize soil erosion and keep the nutrients in their soils (20% of producers in dataset (a) do inter-seasonal cover crops). Cover crops such as *brachiaria* (a variety of grass used for pastures) help pump nutrients from deeper soil layers back to the surface because their roots go 1 meter deep as opposed to an average of 20 or 30 cm for soybean and maize. Another set of producers choose to plant cover crops not just for the interseason but operate a crop rotation for one or two full years, the time needed to restore soil fertility. 11% of producers in dataset (a) did this, as opposed to crop succession (which denotes the succession of soybean and maize within a same agricultural year).

Producers may also diversify the crop varieties they commercialize to cater to different markets or to mix agriculture with ranching or forestry. Producers adopt integrated crop-livestock systems (ILP) or integrated crop-livestock-forestry systems (ILPF), allowing them to minimize financial variability by also commercializing beef and wood products. We found that only 12.5% producers of dataset (a) declared using ILP systems at least on part of their cultivated area. In contrast, ILPF

practices represented less than 1% of Mato Grosso's cultivated area in 2006 according to IBGE's Agricultural Census (J. Gil, Siebold, and Berger 2015).

Such diversified production systems not only reduce financial risks (Merener and Steglich 2018) but also lower environmental risks. The intertemporal management of production by leaving some plots out of production lead producers to restore some of the biodiversity lost through monocropping systems and reduce chemical fertilization of soils.

6. DISCUSSION

As observed over the last decades, the soybean production of Mato Grosso evolved from an expansionist strategy - where producers focused on production through the insertion of new lands into the productivity cycles - to new land and financial management systems demonstrating that producers changed not only the way of managing the agricultural production but also the way they manage and understand the farm system as a whole (i.e., the agricultural and financial dimensions) (**See Annex for summary table**).

Throughout this paper, we described a land-change dynamic that is contingent to the stages of occupation of Mato Grosso's frontier, following the linear evolution of production strategies in municipalities of group 1. However, it is very important to point out that the production strategies are not necessarily contingent to space (i.e. existing in one municipality but not others) and time (e.g. existing only at one given time period) at the landscape scale, when we include group 2 and 3 municipalities. First, the history of municipalities from group 2 and 3 demonstrate that, although they are going through similar stages of occupation as group 1, they do benefit from the

technological advances brought about by pioneering regions (e.g. better soybean varieties, cultivation techniques, etc.). Second, producers within a given municipality may combine agricultural practices pertaining to different categories of production strategies. For instance, producers may be intensifying production at the plot-level (Category C.), while investing in storage facilities (Category D.) and considering expanding further its activities (Category A.) (e.g. to find additional land so that their children can farm too). Producers differ in terms of professionalization, capitalization, and other individual characteristics, which may significantly influence the choice of strategy followed. As of today, dataset (a) demonstrates that very few producers may be involved in practices pertaining to the diversification strategy (Category E.) as only 11% practice crop rotation.

The analysis revealed that each production strategy category both addresses the risks associated with older forms of production, but also create new risks to be addressed by new forms of production. For instance, the no till, double-cropping systems brought about in the 1990s in Mato Grosso (Category B.) had the unintended result to negatively affect soybean yields, as explained in Section 5.2. This system is considered by some specialists as a 'double-edged sword' since it provides a higher output per hectare (i.e. production of soybean plus maize) but increases financial risks by exposing maize to droughts, making soybean harvest difficult during the rainy season, and decreases soybean productivity which may not offset production costs (Silva et al. 2017). To address these new risks farmers were led to adopt a variety of responses. During our fieldwork (in 2017), some producers declared avoiding to plant maize as second-crop or even to plant soybean on the sandier soils of their property (with lower productivity results). As the increase of production costs is squeezing producers' profit margins, intensification at the plot-level (Category

C) increasingly appeared to be the finer scale for decision-making for the property. Sparing land plots from the production of soybean and maize annually for full calendar years opens up the possibility to plant other crop varieties in the meantime (examples observed during fieldwork: sunflower, caupi beans, sesame seed, niger seed, rice, sorghum, brachiaria, fodder turnip, and crotalaria) (Category E.). This way producers both promote the restoration of soil fertility and find alternative income sources by exploring those crops with commercial value. In this context, Category B. practices may lead to Category C. practices, which in turn may lead to Category E. practices.

The linear or non-linear pathways producers follow in changing production strategies help explain the critical importance of the economic, social, ecological, and institutional factors combining to produce such outcomes. One of the motivating questions of this study was to reflect about whether we have reached the end of soybean expansion in Mato Grosso, or if it is "just" a matter of time before new conditions align to allow for more expansion. In other words, are these production strategies simply a consequence of temporary governance and economic conditions? (Arvor et al. 2017). On the one hand, this evolution follows a general trend in Brazilian agribusiness which invites families of producers to move to a more entrepreneurship business model (e.g., by moving the office from the farm to the city, hiring specialized consultants), have family members (e.g., producers' sons and daughters) obtain degrees in higher education (in agronomy, business management or economics), and invest in modern infrastructures such as on-farm storage facilities and crop dryers (requiring new skills to manage such equipment effectively). This movement toward more stable profit margins goes hand-in-hand with sustainable production

systems, as the different categories of production practices and their associated environmental risks have revealed.

On the other hand, however, the way soybean production strategies have changed over the last decades in Mato Grosso State mirrors institutional changes in the Brazilian agribusiness governance and in the international market of commodities (i.e. private-led zero-deforestation initiatives) (Lambin et al. 2018) which impacted differently the various soybean production areas in Brazil. Proof of this is that the deceleration of forest clearing rates since 2004 (**Figure 5.6**) occurred essentially in the Amazon biome and not in the Cerrado biome (Dou et al. 2018). Following a recent example, one may easily speculate that the intensification of soybean production and more difficult conditions of expansion created both by real (e.g. less fertile soils available, land price increases) and artificial land scarcity (e.g. environmental policies putting limits to clearing) in Mato Grosso made soybean production conditions in regions like MATOPIBA[248]all the more attractive despite important biophysical limitations (e.g. higher frequency of droughts, less rainfall, less infrastructures). What would happen to Mato Grosso soybean areas if economic or institutional conditions were to change remains to be seen.

Finally, this study touched upon the causal mechanisms that production strategies represent to explain landscape-level patterns such as land sparing. Thanks to a unique qualitative dataset and extensive fieldwork in soybean production areas of Mato Grosso, we were able to point out the complex conditions that result in shifts in production systems. Nonetheless, there are limitations to our argument both in the data and scope. The message of this study is that various production

[248] An acronym representing four states (Maranhão, Tocantins, Piauí, and Bahia) that represented the largest increase in cultivated soybean area in Brazil in the 2000s and 2010s.

strategies bring about different financial and environmental tradeoffs and give a glimpse at what a production strategy that reduces both types of risk would look like. However, we are neither able to quantify both risks and assess the exact environmental impacts of soybean agriculture as a whole. We believe our study invites further research to re-conceptualize the way they model producer decision-making in regional models, noting that they should define decision-making models contingent to the factors defining each period in the evolution of a frontier. Our data has limitations too, since dataset (a) focused essentially on the largest producers of soybean of Mato Grosso (reminder: the criterion to be included in the sample was to own 2,000 ha or more of land). This allowed us to identify some of the most advanced and innovative production strategies, but this may well misrepresent the extent to which these strategies are shared by producers that are less capitalized. Although we identified producers relying on practices pertaining to strategies C., D. and E., we were also informed by producers that few of the entire population of producers can actually carry them out.

7. CONCLUSION

Our interviews carried out in 2017 with producers showed us that they behave according the political and economic conditions, and play along international commodity scenarios. As players get highly connected to the international dynamics of the agribusiness (Silva et al. 2017; Liu et al. 2013), they are looking for opportunities to increase their competitive advantages, profit margins, market access and to decrease financial risks. They now also need to respect various commitments regarding the environmental performance of their activities if they want to access world markets (Gibbs et al. 2015; Nepstad et al. 2014). This study has outlined the possible improvements in

production practices that could be followed by the sector as a whole, and replicated elsewhere if this model of production were to be exported to new commodity production regions.

Policy-makers and private actors have a very important role to play in this scenario. For instance, the leading association of Mato Grosso's soybean producers, Aprosoja-MT, help producers better negotiate their production, to take decisions about production strategies, to get loans or to access farm credit, and to make producers aware of the importance of sustainable management practices and environmental conservation to allow market access. The Aprosoja-MT also promotes training to the producers and to their family members in order to help them in the transition from a family business to more commercial models and sometimes taking them to Brasília (Federal Capital) to learn about politics and how they can obtain benefits from the political class by behaving as 'big players' of the national economy when they act as group (not as individual producers).

A recent episode in Brazil exemplifies how an innovative agribusiness sector can push for more sustainable production systems. After the Brazilian presidential election of 2018, the elected candidate announced his intention to end the Ministry of Environment (i.e. by merging it to the Ministry of Agriculture) and pulling the country from the 2015 Paris Climate Change Accords. No chances of overturning this decision happened until the agribusiness sector, through representative groups, manifested their concerns about such decisions, arguing that it would threat the sector's international market access. Before long, the elected candidate decided to keep the Ministry of the Environment separate (Watanabe 2018). Governance and economic contexts have a powerful influence on the agribusiness sector as well as on its sustainable development.

Chapter 6: Seeing the environment through the farmers' eyes – environmental perceptions, values, and good agricultural practices

> ***Me**: Why did farmers in Lucas stopped deforesting around 2005?*
> ***Farmer**: Because there was nothing left to clear!*
> *(5 minutes later, still driving around the farm in the SUV)*
> ***Farmer**: See! Here I could have deforested to plant more but I prefer to leave it as it is![249]*

1. INTRODUCTION

The[250] previous chapters have demonstrated that large-scale soybean producers of Mato Grosso are a diverse group of individuals (and families) (Chapter 2), with different environmental behaviors (i.e. different shares of property cleared) which were not necessarily fully a result of either policies or market conditions (Chapter 3 and Chapter 4). Furthermore, Chapter 5 has demonstrated that producers have adopted different production strategies through time, adapting to the changing biophysical and economic conditions in their area, while changing their vision of property management. Whether these changing interactions between producers (and their farms) and the landscape are the cause or the result of changing environmental perceptions and values is a question of utmost interest for explaining behavioral change.

In this chapter, I propose a model describing the evolution of environmental values according to changing environmental perceptions and behavior, and vice versa, since these values also shape these perceptions and behavior. Of course, I cannot discuss the evolution of the environmental

[249] Complementary and follow-up interview conducted in May 2018 with a soybean producer already interviewed in 2017, during a short research trip to share the results of my research with farmers and policy makers

[250] The title of this chapter borrows heavily from Rob Burton's famous paper *Seeing through the 'Good Farmer's' Eyes: Towards Developing an Understanding of the Social Symbolic Value of 'Productivist' Behavior* published in *Sociologia Ruralis*, Volume 44, Issue 2, pages 195-215, on March 19, 2004.

perceptions and values of farmers in a "vacuum" and therefore it is important to bear in mind the historical context and evolution of production strategies analyzed in previous chapters. By *perceptions* I refer here to the *awareness and comprehension of elements in the environment "at large"* (i.e. the natural/physical environment as much as the informational environment, such as changes in market conditions) *and their change over time*. I am interested in how producers change their way of seeing the environment as a result of their actions, and how this might inform their ideas about scarcity in the ecosystem, shaping their future land-uses. Departing from some streams of the socio-psychological literature on environmental literature, I defined *environmental values* in the introduction as the *importance producers attach to particular environmental objects* such as forests, water, and their related ecosystem services such as (local and global) climate regulation. I therefore do not assess other human values using concepts such as "biospheric altruism", "humanistic altruism," or "self-interest" as traditionally defined by the Values-Belief-Norms (VBN) theory or part of the socio-psychological literature (Schwartz and Bilsky 1987; Rokeach 1968; Dietz, Fitzgerald, and Shwom 2005; Tadaki, Sinner, and Chan 2017).

I reviewed the following elements from the semi-structured interviews and this review structures the remainder of this chapter. First, I looked into producers' perceptions and understanding of their environment as of today, especially by examining their perception of the deforestation impacts (i.e. positive or negative aspects). Centering the question around deforestation helped eliciting how producers' perceptions and understanding of deforestation impacts have changed over time, since their landscape referential changed as native vegetation disappears as a result of their doing. Second, I examined their relationship with native vegetation conservation requirements, the Area of Permanent Protection (APP) and the Legal Reserve (LR), as a way to reveal their pro-

environmental values. Because these categories have different purposes in the law (See Chapter 3) and cover different areas on their properties, I expected the producers' answers to vary significantly between each category, in addition of the variability among individuals. Third, I assessed what in their view makes good agricultural practices (GAPs), and which practices they currently implement on their properties. This provided an additional layer of understanding to their environmental behavior as compared to just assessing it through land clearing (Chapter 4). Finally, I created a model of the evolution of environmental values based on changing perceptions and behaviors (i.e. production strategies) informed by the results from this chapter as well as from previous chapters. This last section represents a theorization of the relationship between environmental values, perceptions, and behavior in a changing landscape.

2. PERCEPTIONS ABOUT DEFORESTATION, THE ENVIRONMENT, AND THEMSELVES

Chapter 4 demonstrated that not all areas cleared by large-scale soybean producers were initially covered by forests *stricto sensu.* Instead, it presented a mix of diverse vegetation covers including types of vegetation typical of the Cerrado, such as savannas, bushes, grasslands, etc. As a result, interviewed producers often shared the fact that they did not feel they had deforested in the sense of "clearing forests." In their mind, they rather cleared bushes and thin trees, a version of the story that tends to be confirmed by the clearing techniques mentioned (e.g. steel cable in between two tractors). However, Chapter 4 has also demonstrated that, if producers in the Chapada dos Parecis region do not seem to have cleared much forests in comparison to non-forest Cerrado vegetation, those from the BR-163 region clearly did when the region consolidated in the 1990s and early 2000s. Below, I analyze the answers that producers provided when asked about the positive and negative impacts of deforestation.

2.1. METHODS & DATA ANALYSIS:

The questionnaire applied in this study contained a question about the perceptions that farmers have about the act of clearing land, without specifying if I referred to deforestation in the broader context of the region's colonization or about deforestation today. The question treated deforestation as a generic concept leaving some flexibility to the interviewee to come up with their own interpretation of how to answer the question. The question was located in the third and final part of the interview which I called the "Qualitative" part (after the "Biographic" and the "Quantitative" parts). I recorded answers in a small table listing positive and negative aspects to speed up note-taking. Each interviewee was asked to list up to 3 aspects for each category. When asked about whether there was any specific order of priority in which the elements should be listed, I replied to the interviewee that answers did not need to be in any order to preserve the spontaneous and "natural" order with which interviewees think about these elements. The question was structured as follows:

> ***Portuguese**: "Será que o senhor pode listar 3 aspectos positivos e 3 aspetos negativos do desmatamento?"*
>
> ***English**: "Could you list 3 positive and 3 negative aspects of deforestation?"*

The question yielded a variety of answers, both in the case of positive and negative aspects, which I coded and summarized by themes I defined and which represented what the interviewees spoke about to simplify the analysis. The tables available in the Annex (**Tables 6.a and 6.b**) detail how I interpreted respondents' answers to belong to broader themes. Only when the answers did not represent a "meaningful" theme or did not reflect a particular opinion did I dismiss particular answers from interviewees. This did not happen often, but one example happened with a producer

who mentioned that a negative aspect of deforestation was the "change that occurred" (e.g. ITW n°043: "a mudança que ocorre").[251] Since, I could not interpret further whether the change was environmental or not, I dropped this answer. In a few cases, interviewees missed the point. For instance, one interviewee told me that a "negative" aspect of deforestation was the lack of development ensuing if there was no deforestation (i.e. ITW n°053). This would arguably be a negative aspect of the presence of forests, but not a negative aspect of deforestation.

Following these lists of negative and positive aspects, I created a list of the most commonly cited aspects associated with deforestation by soybean producers. When interviewees mentioned positive or negative aspects that fit two or more categories, I double-coded the aspect. As a result, it is theoretically possible to have a total count of a particular category that exceeds the number of interviewees, but this did not happen because not all interviewees responded the same thing or covered three aspects (some only mentioned one or two). The most common example is when interviewees mentioned that they believed they were both local and global climate change implications to deforestation, or when they thought deforestation would both bring about development and jobs. In such cases, for example, I indicated "1" for development and "1" for jobs. The most commonly cited aspects are indicated in **Table 6.1.**

[251] Only one case (ITW n°043)

Aspects	Positive 1	Positive 2	Positive 3	Negative 1	Negative 2	Negative 3	Total	Rank
Positive aspects								
Production	58	15	5	-	-	-	78	1st
Development	16	19	16	-	-	-	51	2nd
Jobs	5	14	5	-	-	-	24	3rd
Profitability	9	11	3	-	-	-	23	4th
Brazilian development	2	4	1	-	-	-	7	5th
Others	0	3	0	-	-	-	3	6th
Forest management	1	0	1	-	-	-	2	7th
Species Improvement	0	0	2	-	-	-	2	8th
Positive Climate	1	0	1	-	-	-	2	9th
Legal deforestation	1	1	0	-	-	-	2	10th
Negative aspects								
Biodiversity	-	-	-	18	16	1	35	1st
Rivers	-	-	-	15	6	1	22	2nd
Local Climate[252]	-	-	-	12	7	1	20	3rd
Global Climate	-	-	-	5	9	2	16	4th
Improper use	-	-	-	15	0	0	15	5th
Erosion	-	-	-	4	3	4	11	6th
Illegal deforestation (coded "illegal")	-	-	-	7	3	1	11	7th
Disturbance	-	-	-	9	1	1	11	8th
Others	-	-	-	4	3	4	11	9th
Pollution	-	-	-	1	3	2	6	10th
No use	-	-	-	1	1	0	2	11th

Table 6.1. Frequency of positive and negative aspects associated with deforestation by the interviewees. In the top row, the number after each positive and negative word indicate if the aspect was mentioned first, second, or third. **Notes**: (1) Not all interviews started by mentioning positive aspects first and some even mentioned aspects that alternated between positive and negative. (2) A few interviewees mentioned the same aspect twice and is thus double counted for a same individual. Since, these aspects are simplifications of the interviewees' arguments, I decided to keep the double counting since one interviewee can mention an aspect twice because he or she emphasizes different dimensions of it (for instance, if a farmer mentions the positive aspect of regional development and infrastructure creation, both count as "development" here). As a conclusion, this table should be interpreted as the *relative frequency of aspects mentioned* by interviewees.

2.2. Results & discussion: what does deforestation represent to farmers?

I analyzed these results and combined them with interview elements to understand the relationship between deforestation and agricultural production as perceived by farmers. This analysis sheds lights on how farmers perceive elements of the ecosystem differently, and the tradeoffs between agricultural production and nature preservation they acknowledge, something already noted by Dubreuil et al. (2019). Although "buried" deep into the questionnaire, the

[252] Only 5 interviewees mentioned both the local and global climate change as a negative aspects, the remaining interviewees only thought about one or the other.

"mechanical" listing asked by such a question puzzled more than one interviewee. As with other questions in the questionnaire, farmers rightly identified the political sensitivity of the questions and the risks that their answers would carry. Some interviewees were particularly at unease with such a question and made explicit statements to subject their answers to various conditions or nuances (e.g. "first, deforestation is *always* negative" ; "deforestation can only be made within the limits of the law"). This shall not be surprising given how agricultural producers in Brazil, especially soybean producers, have earned over the years the reputation of "bad guys" following NGO campaigns such as the "Eating up the Amazon" campaign in 2006 by Greenpeace (GREENPEACE 2006). Interviewees often made a point that I first mark down that they considered deforestation to be bad or that it should be made within the law, right after which they would say that it is often necessary (there were 14 cases of interviewees putting such a condition to their statements). Beyond the slight imbalance between the number of positive aspects mentioned (194) as opposed to negative aspects mentioned (160), there is much to be said about how producers' perception of deforestation reveal broader elements about their vision of the environment and their identity as producers.

2.2.1. Deforestation as necessary for 'noble' pursuits: food production and security while preserving the soils

> ***English**: "Clear with sustainability, clear with a noble purpose" [ITW n°014]*
>
> ***Portuguese:** "Derrubar com sustentabilidade, derrubar para uma coisa nobra" [ITW n°014]*

The most recurring and widely shared theme in the answers was that, without deforestation, there could be no production of food to feed Brazilians[253] or the rest of the world (mentioned 78 times by farmers). While the majority of producers simply stated that one positive aspect was the production of food, three underlined that it was for the 'survival'[254] of humankind (ITWs n°009, 039, 090). One may interpret this argument, frequently used by the agribusiness sector, as a rebuttal against criticism questioning the implications of export-based intensified monoculture systems. However, others may see in such an argument the expression of an environmental vision grounded into ideas of productivism and serving as the criterion to evaluate whether particular actions with environmental implications are legitimate or not. As such, I am referring to the definition of 'productivist' behavior proposed by Burton, which characterizes the "overwhelmingly utilitarian approach to land use based on intensive forms of agricultural production (and accompanying attitudes, goals, roles and behaviors) that results in a uniform landscape"[255] (Burton 2004: 198). Hence, farmers would mention food production as the main positive aspect because they base their identity around producer roles, such as "feeding the world."

[253] Despite the fact that an overwhelming majority of soybean production in these areas is export-oriented, so does serve the purpose of feeding Brazilians, at least directly

[254] In Portuguese, 'sobrevivência'

[255] To be clear, in his original paper, Burton uses this definition to define what "productivist" means. In what follows I will however use this definition alternatively to describe indiscriminately what is a "productivist behavior" and what is "productivism"

Supporting the idea that farmers' perceptions of deforestation are grounded in productivism, farmers have various opinions about land not put to "good use." A negative aspect frequently identified by farmers is when deforestation is not done in the areas most suitable for agriculture, such as sandy areas (mentioned 15 times) or is not followed by a productive use of land, such as when it is only done to extract specific wood types (mentioned 2 times). In the view of farmers, deforestation is negative in areas which have low soil fertility, but not where the land has agricultural potential (e.g. ITW n°079). In short, improper land-use or absence of land-use (negative) aspects are the symmetrical oppositve of the (positive) aspect of food production.

Productivism also helps them discriminating against the types of deforestation done by other groups such as *garimpeiros* (i.e. gold miners), loggers or cattle-ranchers. For instance, one farmer mentioned the "distortions of illegal deforestation done by *garimpeiros* or wood exploration" (ITW n°026). A couple of other farmers reinforced that view by making two different statements:

> *"Deforestation for wood only, farmers do not do that. The logger deforests and goes away, leaving land behind her"*[256] *(ITW n°042)*
>
> *"Deforestation only makes sense insofar as it is done for a useful purpose. Many areas were deforested only for wood extraction, it does not make sense"*[257] *(ITW n°048)*
>
> *"Deforestation without criterion has a huge impact on nature, the cattle-ranching activity degrades land"*[258] *(ITW n°009)*

This distinction between the activity of soybean producers as having a superior legitimacy to that of other land users in the Amazon region is pervasive in the farmers' discourse, either explicitly

[256] Original quote in Portuguese: "desmatamento para madeira só, o agricultor nao faz isso. O madeireiro desmata e vai embora deixando a terra por atras"

[257] Original quote in Portuguese "O desmatamento so faz sentido só se for usado para uma coisa útil. Teve muitas áreas que forma desmatadas so pela madeira, não faz sentido"

[258] Original quote in Portuguese "Desmatamento sem critério tem impacto grande na natureza, a atividade pecuária degrade as terras".

(3 producers criticizing mining and ranching) or implicitly when referring to the production of food (58 producers mentioned this) or, as already mentioned above, when referring to the "proper" soil use (15 producers mentioned this). Of course, cattle-ranching produces food too. The underlying reasoning of producers is that, of all activities taking place in the frontiers such as mining, ranching, or agriculture (all of which producing wealth), agriculture is the most legitimate because it produces food without degrading the land (as opposed to cattle-ranching) and is oriented over the long-term (as opposed to the short-term horizon of loggers and cattle-ranchers). Another element supports this idea that the activity of farmers is superior to that of other agents of the frontier. When asked about good agricultural practices (see next section), farmers mentioned frequently the need to take "good care" of the soils and restore their fertility. As Empinotti explains about soybean farmers of the Cerrado: "Farmers in the Cerrado believe that agricultural practices are improving the environment once soil fertility levels improved from natural levels" (Empinotti 2018: 17).

It is the soybean producers' version of productivism that structures the core spectrum based on which they assess whether nature should be used or not. Simply put, if a land is flat and suitable for agriculture, then the area should be cleared for the good of the many, if it is located in sandy areas near rivers or around slopes and hills, there is no point in clearing it because it will barely produce or not produce at all. Other studies with soybean producers in Mato Grosso have pointed out to this utilitarian relationship between farmers and nature: "soybean/corn producers will not deforest riparian vegetation conservation areas because the Forest Code restricts such a practice but simply because of the natural low fertility and physical characteristics of soils (sandy soils)

that require high investments that make agricultural production uneconomical" (Empinotti 2018: 17-18).

In sum, sustainable crop production while preserving (or even restoring) soil fertility is the defining feature of large-scale soybean producers of the study area (**Dubreuil 2019**). They derive great pride from this, and they self-identify not only as the most legitimate users of the land, but also as the most prestigious workers in the area. Traveling along the BR-163 in the 2000s, anthropologist Bill Fisher had already remarked that:

> *"it's not wealth alone that elicits admiration and emulation in Sorriso, but wealth gained through industrial farming. Logging and cattle ranching as well as commerce and building trades are other prominent industries, but farming is the measure by which status can most effectively be displayed" (Fisher 2007: 353).*

He also noted that in Sorriso, producers have a yearly-award for best producer established by the Commercial and Industrial Association of Sorriso while others professions tend to seek mutual recognition in the Rotary Club. I however noticed during my fieldwork that many large-scale producers are also part of the local Rotary Club.

2.2.2. Deforestation as a necessary step for development

Another key aspect to the legitimacy of converting forests into fields is linked to the idea that agriculture would be the driving force behind further economic and social development in their municipality and in their region (mentioned 51 times). Thus, deforestation is a noble pursuit and a "step in development" (ITW n°089) because schools, hospitals and other businesses would not arrive without the process of forest conversion into agriculture. A farmer summarized how they usually see the place of agriculture in society: "it drives everything (…), we import machines from

the U.S. Wealth only comes because there is deforestation. It's a cog in the wheel helping everything to work and grow, like state and national development (…)"[259] (ITW n°049). Another aspect is that farmers take pride in the fact that most of the revenue they generate stays within the state for the development of the state, perhaps unlike other economic activities where revenues may be concentrated in the economic capitals of Brazil or abroad (Rachael D. Garrett and Rausch 2016). Agriculture indeed represents more than half of the GDP of the state of Mato Grosso (Empinotti 2016) and a third of Brazil (Chaddad and Jank 2006). The whole Brazilian soybean supply chain, however, contributed to 0.7% of the total GDP in 2007 (Rachael D. Garrett and Rausch 2016). Combined with sugarcane and maize, it represented 3.4% of the GDP in 2016 (Trase 2018).[260]

In the producer's view, agricultural expansion generates many on-farm and off-farm (i.e. in the city) jobs (mentioned 24 times), contributing to further development and distribute wealth at the local level. This view is comforted by the fact that these farmers often struggle to find workers, especially skilled ones, for their farm operations. Various studies have acknowledge the positive impact of the soybean sector on job generation, both on-farm and off-farm, in storage units, cooperatives, input reseller stores, or in local stores in urban areas (Martinelli et al. 2017; Weinhold, Killick, and Reis 2013b; Rachael D. Garrett and Rausch 2016; P. Richards et al. 2015).

[259] Excerpts of the original quote in Portuguese: "gera tudo, mecânico, importamos maquinários do EUA, a riqueza so vem porque teve desmatamento. E o desenvolvimento estadual, nacional, é uma engranagem, tudo vai girando e crescendo, se você começa a formar os filhos"

[260] Such numbers should be taken with caution since they do not account all for the same activities. Chaddad and Jank (2006) came up with a very large number because they counted all activities related to the agricultural sectors (in industry and services) and probably those happening in areas dominated by agriculture. On the contrary, the numbers from Garrett and Rausch (2016) and Trase (2018) rely on official accounting categories.

Producers frequently mentioned that their activity helped maintaining the Brazilian economy in a less dire state than it would be without them (mentioned 7 times[261]). The agricultural sector -in general- represents about one third of the Brazilian GDP and farmers know well the extent to which they contribute to supporting a positive balance of payments (Chaddad and Jank 2006). They further take some pride in being the "leader in the production of commodities and a food supplier of the world"[262] (ITW n° 008). This evidence sheds light on how farmers perceive the far-reaching implications of their economic activity as transcending the local scale.

These aspects feed into a narrative according to which agricultural expansion over forests is legitimate and is a 'noble' pursuit, in the sense that farmers contribute through their activity to the common good at different scales: local, regional, national, and worldwide. Thus, a few farmers do not hesitate to affirm that deforestation has no negative aspects as long as it is practiced with respect of the current property and environmental legislation (11 producers stated this):

> *"I do not see any negative aspects provided that it is done within the respect of the limits. The fauna and flora benefitted a lot from agriculture. There has been a multiplication of animals, the jaguar came back too! There is a myth conveyed by environmentalists" [ITW n°023].*

This quote shows us how some producers attempt to legitimate deforestation by an assumed positive contribution to another part of the landscape (i.e. wildlife). Although I will discuss below the environmental implications of this quote, it is important to underline here that the "legitimization" of agricultural expansion through deforestation uses an environmental rhetoric

[261] I would not be able to restitute in quantitative terms how much farmers and their representative associations tend to underline this point too often. 7 times may appear as a low number, but it was measuring the number of times they mentioned this aspect *during that question*. I very often heard the argument in off-conversations with farmers and local and state agricultural leaders.

[262] Original quote in Portuguese: "líder em produção de commodities e fornecedor de alimentos"

justifying negative outcomes (i.e. deforestation) by positive outcomes (i.e. more wildlife). In their view, the fact that most deforestation was done legally in the sense of respecting the "original" percentage of the Legal Reserve (LR) applying to Cerrado-dominated areas (20% between 1989 and 2001) reinforces its legitimacy.[263] Five producers referred to the law as a dimension that made deforestation acceptable. Of those, two pointed out that deforestation must be done within the law (positive aspect), and three explained that deforestation was wrong when it was carried out illegally (negative aspect). As Chapter 4 revealed, the fact that many farmers in these areas may still have important areas of their farms exceeding LR requirements may explain why they want to reserve the right to further deforest if they need additional planted area in the future. In other parts of the interview producers often pointed out that the federal and state institutions "encouraged" them to deforest in the past: "I am going to tell you a fun story. At one time, the government supported the settlers here in Lucas to clear land. After they opened too much, the government came back to control and sanction" [ITW n°016].[264] It is well-known that the INCRA imposed and still imposes the clearing of land as a necessary condition for titling land (Tourneau and Bursztyn 2011). If the general intent of the government was indeed to encourage clearing, it is however doubtful that producers settled through private colonization had the same pressure to clear forests that those who settled through other ways.

[263] This, regardless of the fact that many deforested after the percentage increased to 35%, or that many deforested more than what was authorized because they were either in forest transition areas were percentages were higher.

[264] Original quote in Portuguese: "Vou te contar uma historia engraçada. Numa época o governo apoiou os assentados aqui em Lucas para abrir. Depois eles abriram demais, e o governo voltou para fiscalizar e punir" [ITW n°015]

2.2.3. Deforestation as the 'only' or the 'old' way for improving the profitability of the farm

Reinforcing that impression that many producers still consider the possibility of deforesting, at least from a theoretical standpoint, 23 producers still considered deforestation and the expansion over new areas as a way to increase economic rent. In spite of the deep turn toward agricultural intensification in the region, some still consider expansion over new areas as an important way to increase profitability: "you cannot increase the rent without deforesting"[265] (ITW n°011). Others underlined the fact that, since the times deforestation had been encouraged by the government, land always has more value once it is stripped of its vegetation, which is common knowledge in the Amazon (e.g. ITW n°078). Finally, some recognized that land clearing contributed to the "maintenance and development of the family"[266] (ITW n°007). As pointed out in Chapter 5, intensification does not necessarily means that there will be lesser deforestation, simply because it increases the opportunity costs of deforestation by making the per-hectare soybean production more profitable.

To further understand this, however, it is necessary to put things into perspective by asking the question: Under which circumstances would soybean producers leave their land to purchase land somewhere else? Many producers today are going through or anticipating the moment where they will have to transfer the farm control to their children, a process known as family succession (See Chapter 2). They realize that, in order to be profitable according to an average farm profitability model[267] in Mato Grosso involves planting over 1,000 hectares of land. Hence, farmers owning

[265] Original quote in Portuguese: "Você não consegue aumentar a renda menos ter que desmatar"
[266] Original quote in Portuguese: "manutenção e desenvolvimento da família"
[267] Producers often referred to that model in an abstract way, without exactly explaining what it entailed. Producers below 1,000 ha can perfectly be profitable. Throughout various conversations I had with producers and other actors in the region, it seemed however more difficult to be profitable under 1,000 ha than above.

around 2,000 hectares realize that, once the property will be divided among multiple children, their children may not have the conditions to sustain agricultural production for long in ever-changing market conditions. At this key turning point, producer families either plan to clear additional land on their property or to sell their current property to acquire a larger one in one of the neighboring municipalities, or go into another state, in the newest frontiers of soybean production. It was the case of a family of farmers (i.e. ITW n°027 & ITW n°029) who decided to sell their 600 ha property in Sorriso to buy around 5,000 ha in the municipality of Vera, thus enabling the family to pursue the activity over the long-term.

It is nonetheless noticeable that, for a strategy that has underpinned the whole existence and life trajectories of these producers, they only mentioned it 23 times. It demonstrates that the profitability of a farm rests today much more on other aspects such as the "verticalization" of production processes (e.g. better equipment such as storage and crop dryers, or improvements in management processes) and investments in agricultural intensification. This constitutes a real shift in perspective from the colonization period of the 1970s-1980s, as well as the period of consolidation of the 1990s and early-2000s.

2.2.4. Environmental implications of deforestation: an understanding limited to local impacts

Turning to the negative aspects of deforestation, soybean producers overwhelmingly mentioned *local* aspects, when they did not mention the "disturbance" caused by deforestation in general (11 mentions). The primary concern was that deforestation degraded the natural habitat of local species (animal and vegetation) and may decrease their number. Yet, throughout the interviews I often heard anecdotes about how animals living in the forest reserves of the properties tended to feed off

the crops, contributing to a perception according to which agriculture would be good for wildlife (see above quote from ITW n°023). Producers mentioned that the number of birds increased, that wild boars[268] were multiplying and decimating crops, or that they sometimes harvested with a jaguar walking near them in the field.[269] I witnessed several times the kind of "wildlife scenes" that producers referred to, generally as I was driving down farm roads and suddenly saw wild boars or monkeys eating or snatching soybean and corn crops. Although not disputing the reality of such phenomenon, one may question whether animals are not appearing more because of the reduction of their habitat since the 1980s and the scarcity of preys or the reduction of their food base in general.

This type of producer perception may lead some to "extreme" positions as some farmers tended to claim positive impacts of agriculture on the environment. There were 2 mentions of how the local fauna benefits off agricultural activities (i.e. species improvement) and 2 mentions of how the soybean and maize crop cover provides a "greener" cover than Cerrado's native vegetation, influencing positively the local climate. One farmer thus stated a quite contradictory opinion about trees:

> *"The old tree pollutes more (no NGOs talk about this!) but when the tree dies it liberates more methane also, which is more harmful than carbon. Take out trees to let new trees grow (forest management) is good" (ITW n°033).*[270]

[268] Translated from the Portuguese "porcos-do-mato."

[269] They showed me videos of this on their cell phone, hence it is impossible to know neither when nor where these videos were taken (it could have been in another state). I however walked in one field that had been stepped upon by a heard of wild boars and could assess with my own eyes the extent of crop destruction. In general, destroyed areas are fairly small as compared to the overall property size.

[270] Original quote in Portuguese: "A árvore velha polui mais (nenhuma ONG fala disso !) mas quando cai a árvore libera mais metano também que é mais nocivo que o carbono. Tirar mato para deixar uma nova árvore crescer (manejo florestal) é bom."

However, far from this extreme position, many farmers know well that their activity degrades the environment and do not hide it, many declaring that they did not see any positive aspects to it before answering to the question. Supporting this point, one may notice that environmental aspects were mentioned only 8 times out of 196 positive aspects to deforestation. On the contrary, the environment was the overwhelming theme within negative aspects.

The second aspect often mentioned was the impact that deforestation causes to rivers (mentioned 15 times) by drying them up or destroying local springs ("*nascentes"* in Portuguese). Producers seemed to value water particularly strongly, for a variety of reasons (see below part on environmental values). One farmer mentioned as an impact of deforestation (although it is not really one) how immoral it was to use irrigation water for harvests when there is already abundant rain:

> *"I think it is wrong to use irrigation, to clear [land] up to the river. I think it is immoral to use river water when rainfall here already allows to do two harvests" [ITW n°096]*[271]

Beyond just the reduction in water availability that deforestation can cause to rivers, producers also mentioned the erosion of soils and flowing of sediments into streams (11 mentions). No till systems and bench terraces have particularly reduced erosion in Mato Grosso and producers realize the importance of these techniques to reduce environmental impacts (e.g. ITW n°062 and 065). 6 producers mentioned that some pollution was created out of deforestation, but they did not specify it further and linked it to a specific impact on the landscape. It is therefore difficult to know whether

[271] Original quote in Portuguese: "Eu acho errado de mexer com irrigação, de derrubar até o rio. Eu acho imoral de usar a agua do rio quando a chuva aqui já te permite fazer duas safras"

they referred to the pollution of rivers through erosion and agrochemical use or the atmospheric pollution resulting from burning cleared vegetation.

Producers' perceptions of climate change represent an interesting puzzle (Dubreuil et al. 2019). Producers clearly separate the *local* and *global* aspects of climatic change. As remarked by others, discussing about climate change with producers is made ambiguous by the fact that the word "clima" in Portuguese may well refer to "weather" or "climate" at the same time (Rausch 2013). Generally speaking, the number of producers that recognized the impacts of deforestation on both local and global climates is surprisingly small. Only 20 recognized local climate change and 16 recognized global climate change impacts.

Global climate change was especially subject to the skepticism of producers. Numerous farmers did not "believe" in the fact that climate change was caused or aggravated by deforestation, or if they did, they assessed this contribution to be very limited. As one interviewee put it: "It interferes with the climate but less than the sea, the oceans" [ITW n°033].[272] This distrust in the causes of climate change finds it source in their perception of the science on the topic. One interviewee declared: "On climate change, there are no studies, just opinions" [ITW n°067].[273] Another said: "I do not think that the climate changes with this [deforestation] but all the scientists say that it does" [ITW n°065].[274] Producers frequently referred to an influential and viral video that circulated on the Whatsapp of producers and viewed 1.6 million times on Youtube (as of March 9, 2019)

[272] Original quote in Portuguese: "Interfere com clima mas menos que o mar, os oceanos" [ITW n°033]
[273] Original quote in Portuguese: "Sobre o clima, não tem estudos, só tem opinião" [ITW n°067]
[274] Original quote in Portuguese: "Eu nao acho que o clima muda com isso mas todos cientistas falam que sim " [ITW n°065]

where a professor of the University of São Paulo[275] is interviewed in the TV program "O Programa do Jô." In this sequence, this professor argues that "rain does not happen because of trees, trees occur because it rains,"[276] a rhetoric frequently used by producers denying climate change. A few farmers repeated the exact same quote to me (e.g. ITW n°050) or made a direct reference to this video when talking about the environment (e.g. ITW n°070).

A minority of producers nonetheless recognize the global climate change impacts of deforestation (16 mentions), but only limitedly so or maintaining a certain degree of skepticism. For instance, one interviewee recognized all the impacts of climate change, but attached a caveat to his statement indicating that he had some doubts about the degree to which his version of the facts was true or not:

> *"I do not know how much of this is the truth, but it probably affects the global climate. It includes the fact that, if there are alterations, there is a conscious that the first to be affected will be the farmers. There are natural cycles, but we need to avoid the acceleration of those cycles, or more brutal changes" [ITW n°022]*[277]

A same producer could well negate some climate change aspects while acknowledging others. For instance, a farmer stated that the double-cropping system based on soybean and corn crop cover provided for a "better" (or at least "greener") vegetation area than the native vegetation cover of the Cerrado, but he also stated that:

> *"Continuous deforestation, independently of climate events (because it is not possible to know if it was because the land*

[275] Professor Ricardo Augusto Felício

[276] Youtube video named "Professor da USP Revela A Farsa do Aquecimento Global no PROGRAMA DO JÔ! (ENTREVISTA COMPLETA)". The video can be found at the following URL: https://www.youtube.com/watch?v=NYLDDnrNlo4 [Accessed March 9, 2019]

[277] Original quote in Portuguese: "não sei quanto é a verdade, mas provavelmente afeita o clima global. Inclusive, se tiver alterações, existe a consciência que os primeiros afeitados serão os agricultores. Existem ciclos naturais, mas a gente tem que evitar aceleração desses ciclos, ou mudanças mais brutais" [ITW n°048]

> *cover was removed), will increase soil temperature, the drying of the soil (with the increase in wind speed). It introduces an imbalance at the level of the soil" [ITW n°022]*[278]

He recognizes that the removal of trees will lead to increase soil temperatures and cause droughts, but he is unsure there is a link between this fact and global climate change. This contradiction is even more striking since this farmer recognizes other environmental damages on soil fertility.

More farmers were concerned by the *local* climate implications of deforestation (20 mentions) than the global ones. This concern for local changes revolves essentially around the transformation of rainfall patterns and local warming. After residing several decades in the area, some farmers started noticing changes in the changing distribution and concentration of rainfall. For instance, a producer who resided 32 years in the area shared his perception of rainfall patterns:

> *"It affects the environment and the climate, today is not like 5-6 years ago. There is no more rain in October. I believe that it affects the global climate too. Today, we get 200 mm of rain, it is not like the 'small' rain of 50 mm that we used to get before. This is why we produce more each time with what we have, without clearing more"*[279] *[ITW n°091].*[280]

Similarly to implications for global climate change, producers also shared their doubts about whether this change of rainfall pattern is real. For instance, an interviewee referred to the perception of his parents and their past experiences:

[278] Original quote in Portuguese: "o desmatamento continuo, independentemente de eventos no clima (porque nao da pra saber se é porque tirou a cobertura), vai aumentar a temperatura do solo, o ressecamento do solo (com velocidade do vento mais alta). Introduz um desequilibro ao nível do solo" [ITW n°022]

[279] The rainfall volume evoked by this producer has to be put into perspective. He most likely speaks about rain events that last a day. Before he felt the rainfall volume was distributed more evenly across the days of the month, but today 200 mm of rainfall can drop in a single day. According to EMBRAPA, the maximum daily average rainfall varies between 108.8 mm and 220 mm in Mato Grosso (Fietz et al. 2010).

[280] Original quote in Portuguese: "mexe com o meio ambiente e o clima, hoje ja nao é como a 5-6 anos atrás. Nao chove mais em otbro. Eu acho que tem um efeito no clima global também. Nos pegamos hoje 200mm de chuva, nao é como aquela chuvinha de 50mm que tínhamos antes. É por isso que hoje produzimos cada vez mais com o que temos, sem abrir mais" [ITW n°091]

> *"I do not know up to which point it affects the climate. In Rio Grande do Sul in 1940, there was a drought that lasted 6 months and nothing had been cleared at the time. The greenhouse [effect], the ozone layer, it can clearly affect [the climate] but I am not sure up to what point" [ITW n°077]*[281]

Producers who mentioned that they were witnessing the warming of the local climate tended to separate it from the change of rainfall patterns (in length, frequency, intensity and regularity). Importantly, producers who know different landscape contexts are able to witness key interactions between the presence of forests and rains at the farm-level. One farmer who had two properties, one of which was cornered by other fields while the other was near a fully-preserved indigenous reserve, responded to my question regarding the negative impacts of deforestation as follows:

> *"The imbalance in the local climate, the rains. The soil does not absorb water, the roots are not deep enough. Close to the indigenous reserve I can see that it helps stabilizing the climate of the place. There is also a greater diversity of insects" [ITW n°103]*[282]

The fact that this producer is able to witness such dramatic differences on so many levels begs the question of whether all these benefits are attributable merely to the presence of forests. He could simply be located in an area where neighbors use more or less pesticides which may impact the level of pests he experiences. Nonetheless, this statement brings supporting evidence to the fact that the native vegetation cover affects local humidity and water levels.

[281] Original quote in Portuguese: "Nao sei até que ponto afeita o clima. No RS em 1940 teve uma seca de 6 meses e tinha nada de derrubado na época. O estufa, a câmara de ozono, claro que pode afeitar mas eu nao sei até que ponto" [ITW n°077]

[282] Original quote in Portuguese: "desequilibra no clima local, as chuvas. O solo não capturar a agua, as raízes não são bastante profunda. Perto da reserva indígena eu vejo que ajuda estabilizar o clima do lugar. Tem também mais variedade de insetos" [ITW n°103]

2.2.5. Deforestation perceptions reveal the building blocks of producer identity

Overall, the perceived positive and negative impacts of deforestation reveal that producers share in common a representation of what they do and a definition of their societal role. The repetition of the production-development-jobs or production-development-profitability (positive) aspects of deforestation show that they strongly identify with "productivist" or "developmentist" roles. As a reminder, the positive implications of deforestation was mentioned 78 times for production, 51 times for development, 24 times for job creation, and 23 times for profitability. While they have not much doubt that deforestation and the subsequent production of crops positively contributes to society, the same confidence is not shared for negative aspects which present a much more scattered distribution. In contrast with producer roles, the negative aspects for deforestation were mentioned 35 times for biodiversity, 33 times for river-related outcomes (impacts on rivers and erosion), 20 times for the local climate, and 16 times for the local climate. A little above half the interviewees (n=60) recognized *at least* one of the following three adverse impacts of deforestation: reduction of wildlife habitats, impact on rivers, changes in local or global climate. Around a third (n=22), however, recognized at least two of them.

These dimensions of deforestation perceptions reveal the building blocks of the self-defined identity (hereafter "self-identity") of this group of farmers built around an idea of what sustainable land-use should look like (i.e. high-output intensified monoculture systems). They derive symbolic value and social prestige from the way they deal with the land, and especially how they care about soil fertility, by stating that they make a "noble" or "legitimate" use of the land as opposed to other land-users (loggers, miners, cattle-ranchers, and so forth) or other citizens (urban workers). Their use of an environmental rhetoric (i.e. soil fertility) and the low number of producers still believing

deforestation is the only way to derive profit mark an identity shift with past frontier history. It was indeed extremely surprising that none of the producers referred to the role of early deforesters as pioneers ("*desbravadores"* in Portuguese), an identity that is yet usually widely shared among the community (Lucidio 2017). This may reveal a change in the agricultural paradigm in the region, where the most praised figure is not the pioneer who produces soybean extensively anymore (focusing on production volume only), but rather the entrepreneurial producer making production decisions based on market profitability and relying on the best technology for production (See Chapter 5). The following sections on good agricultural practices and environmental values further supports that idea.

2.3. DEFINING THE ENVIRONMENT: "ONE SIDE IS GOOD, BUT THE OTHER SIDE BOTHERS US"

During the interviews, I also asked producers what their "definition of the environment" would be. This question unsettled a few farmers but surprisingly most producers accepted to answer. The way producers responded varied quite a lot, some providing me with general definitions of the environment (61 producers) while others listed all the elements of the environment they could think about (or only one aspect) (11 producers). A substantial number of interviewees went off and used the question to make a political statement (24 producers), among which some simply vented about how NGOs "demonize" them or how urban dwellers in cities are not held to the same standards than they are (14 producers). Overall, it is difficult to draw any interpretation from this question. Answers nonetheless bring an interesting complement to deforestation perceptions since they confirm that producers generally perceive themselves as an inherent part of the environment (38 producers) which they need to use for production while respecting some balance (17 producers). Very few producers talked about the environment as something to be preserved for its

own sake, as having an intrinsic value (7 producers), or necessary to maintain opportunities for future generations (3 producers).

General definitions given by producers were often too short to derive any sort of interpretation. For example, interviewee n°095 replied by saying "the environment is necessary" while interviewee n°042 replied that "it is the place where we live and we need to preserve it. Good health depends on the environment." Others made long statements, giving more details about their thinking:

> *"To me, the environment is not only the biological part, it is something larger that encompasses the impacts caused by human actions onto the environment (…) It is not "preserving" but rather "using without degrading," I think this [distinction] is important. Using good agricultural technologies but also with initiatives in the city also. Here in the municipality there is no sewage for instance" [ITW n°002]*[283]

> *"It is maintaining the balance, the trees, production, rivers, and springs. I agree very much with this last point. Many people destroyed springs, you see that it is a crime. It is not possible to understand why some did this. The APPs, the preservation, the reserves, are all fundamental, there has to be a synergy. There are sandy areas, I do not understand why so many people cleared these areas. This past generation had no consciousness. I think it is a matter of education. In the past, very few thought about making money in the future. I think that today, people think they are going to earn more money because of this, because of more preservation" [ITW n°094]*[284]

[283] Original quote in Portuguese: "Para mim o meio ambiente nao só é a parte biológica, é algo amplo que envolve a ação que o ser humano causa no meio ambiente, (…). Não é como 'preservar' é mais 'utilizar sem degradar', acho isso importante. Usando as boas tecnologias agrícolas mas também com ação dentro da cidade também. Aqui no município não tem saneamento por exemplo" [ITW n°002]

[284] Original quote in Portuguese: "É manter o equilibro, as arvores, produção, rios, nascentes. Eu concordo muito com esse ultimo ponto. Teve muitas pessoas que acabaram com nascentes, você vê esse écrime. Nem da para entender por que algumas pessoas fizeram isso. As APPs, a preservação, as reservas sao fundamentais, tem que ter uma sinergia. Tem área arenosa, eu nao entendo porque tantas pessoas abriram essas áreas. Essa geração passada nao tinha a consciência. Eu acho que é a coisa de educação. No passado pouco pensaram em ganhar dinheiro no futuro. Eu acho que hoje, o pessoal pensam que vao ganhar mais no futuro por causa disso, de mais preservação" [ITW n°094]

These two quotes illustrate well the thinking of producers and the change in mindset between "pioneers" to "entrepreneurs" that occurred over several decades in the area. In their view, soybean production should take place without causing excessive harm to the environment and should be "reasoned" in the sense of making utilitarian decisions about the environment. The second quote illustrates this: for part of the producers, it makes no sense to destroy water resources (i.e. springs) to plant more, or clear areas that will not provide high yields (i.e. sandy areas).

Producers were keen on criticizing the discourse of environmental NGOs that made them the "bad guys" of the Amazon. First, they dismissed their criticism by arguing that they preserved a substantial share of the native vegetation, and shared their impression that such criticism was a direct result of the assumed foreign funding of these NGOs. Second, they pointed out to the irony of receiving criticism from urbanites because of the intense pollution occurring in rivers running through cities in the South of Brazil (e.g. São Paulo) or the absence of sewage systems in their own cities. They often argued that they recycled all their agrochemicals packages.

In sum, in the minds of producers, the idea that the "environment" is a "partner" of production co-exists with the view that the "environment" is a concept manipulated by NGOs and governmental bodies to hinder them. The terms of that relationship are mostly dictated by production considerations rather than non-utilitarian consideration, although producers showed their attachment to forests in riparian areas (the APPs) in other parts of the questionnaire (See section on environmental values). In one sense, a farmer summed up their vision pretty well: "One side of it is good, but the other side bothers us" [ITW n°030].[285] These definitions show how the

[285] Original quote in Portuguese: "É bom de um lado, mas o outro lado nos incomoda" [ITW n°030]

environment may have passed from something that represented an "obstacle" to production in the early stage of the frontier to something that needs to be "managed" according to utilitarian criteria today. This last aspect is reflected in the environmental values they derive from the landscape, analyzed in the following section.

3. PRO-ENVIRONMENTAL VALUES: THREE WAYS OF VALUING FORESTS

3.1. METHODS AND DATA

The review of producers' environmental perceptions provided a first look into what the environmental values of soybean producers could be. However, as the discussion on perceptions was broader and spoke to some of the elements of the identity of farmers, I chosed a more specific conceptualization and measure for environmental values to allow for statistical analysis later on. As explained in the introduction to this chapter, and in order to avoid any loose conceptual definition, I chose to call "environmental values" the *importance producers attach to particular environmental objects* such as forests, water, and their related ecosystem services such as (local and global) climate regulation.

A fairly simplistic, but relevant, measure of environmental values was created based on two questions where farmers had to indicate what they believe the role of areas of native vegetation and forests on their property is. The first question was "What is the role of the Area of Permanent Protection (APP)?" and the second question was "What is the role of the Legal Reserve (LR)?" Farmers mostly evoked three types of positive interactions of forests throughout their answers, it thus represents *pro*-environmental values. I identified these values based on farmers' statements linking the importance of landscape features (e.g. forests) in perpetuating desirable ecosystem

services (e.g. protecting water, biodiversity, climate's balance), following other studies that have operated similar "ad hoc" conceptualizations (Klain et al. 2017; Vignola et al. 2010). As a result, I defined three types of pro-environmental values: a water value, a biodiversity value, and a climate value. I explain below the meaning and content of such pro-environmental values.

3.2. A MIXTURE OF WATER, BIODIVERSITY, AND CLIMATE VALUES

The *water value* refers to the reported concern of farmers for water conservation, cleanliness (i.e. pollution-free), and availability. Producers made a reference to the importance of native vegetation for water 78 times for the question on APPs and 22 times for the questions on LRs. In total across the two questions, 79 producers mentioned this role for water, indicating that 21 producers recognize the role of *both* APPs and LRs in the provision of water. Farmers expressed this attachment to water services through statements such as *"[the APP] allows for the conservation of water and springs"* [ITW n°006], *"[the APP] is here to guarantee that erosion and chemicals do not get to the river"* [ITW n°020] or *"[the APP] serves to protect springs, avoid drought, because springs feed into small, medium, and then large rivers that ultimately go to the sea. It's fundamental"* [ITW n°053].

In the case of APPs, the overwhelming majority of producers simply state that these areas are important to preserve water (and wildlife). Some expanded further to explain that they value water in a fairly abstract, non-utilitarian way, recognizing the importance of forest cover for its own sake.

> *"If there is something I agree with the 'eco-chatos' [i.e. 'annoying environmentalists'] is that we need to do everything to preserve water. It is vital for life" [ITW n°027]*[286]

[286] Original quote in Portuguese: "se tem uma coisa com que concordo com os 'eco-chatos' é que temos que fazer tudo para preservar a agua. É vital para a vida" [ITW n°027]

Part of the producers also recognized that there is a utilitarian argument not to use these areas:

> *"For us, these areas have such a small importance but it has such a big importance for the environment that we preserve. It's an area with a lot of trees and sand" [ITW n°004]*[287]

> *"It's protecting areas not suitable for production (...)" [ITW n°048]*[288]

Therefore, producers also value such areas for their ecosystem services because they would hardly be able to plant anything while deriving a profit from them, an observation already made elsewhere in Mato Grosso (Empinotti 2016). Beyond this, there is also a utilitarian aspect to valuing APPs for their water services for irrigation or other uses in the future: "The protection of water is our patrimony. We have to preserve so that we can use it tomorrow if we need it" [ITW n°018].[289]

The *biodiversity value* refers to the importance that farmers express to keep native vegetation as is for the purpose of maintaining ecosystem balance, and the survival of a broad diversity of animals, insects, and other organisms. Producers mentioned this aspect 22 times for APPs and 42 times for LRs (with 50 producers recognizing such aspects if we take both APPs and LRs into account). They expressed the role of both areas in producing biodiversity services with statements such as *"It's the preservation of fishes, also, animals. There are so many animals today, giant wild boars in the middle of the forest, they need to live also"* [interview 064], *"maintain nature alive"* [interview 007], or *"maintain the balance, the ecosystem, animal life, for future generations"* [interview 008].

[287] Original quote in Portuguese: "Para nos essas áreas tem uma importância tao pequena mais tao grande para o meio ambiente que preservamos. É uma área com muitas arvores e arenosa" [ITW n°004]

[288] Original quote in Portuguese: "É proteger as áreas não aptas a produção" [ITW n°048]

[289] Original quote in Portuguese: "A proteçao das aguas, é nosso patrimônio. Temos que preservar para que se amanha precisarmos podemos usar" [ITW n°018]

Contrary to the APPs, The LRs were subject to more rejection and criticism regarding their role. 6 producers criticized harshly the way LRs were designed in the legislation, refusing that such a large part of their property be preserved, especially in areas they deemed productive. 18 producers had softer criticism, recognizing the importance of the LR but stating they would prefer if it was smaller, or redesigned into larger APP areas:

> *"For me, it represents the law requirement, the maintenance of biodiversity. But it does not work, these are separated patches, 'islands', without connection. It would be better if the requirement was that LRs fit into the APPs" [ITW n°025]*[290]

Some also pointed out that they were taking the responsibility of maintaining ecosystem services for the rest of Brazilian society and the world. Surprisingly, only 3 producers mentioned the fact that they would prefer to be compensated monetarily for preserving forests for the rest of the world:

> *"It is the burden we bear. It should be divided among all. Why do you have 80% protected here and not in São Paulo? The purchasers are going to have to pay. There is a moment at which the consumer is going to pay for this. We want our consumer to recognize this, that they recognize the value that we have the most stringent forest code. APROSOJA is working in that sense right now" [ITW n°027]*[291]

This may indicate that producers are more keen on recognizing the global implications of forest preservation when they talk about the benefits they bring rather than the damages (see discussion above on recognize mostly the local implications of deforestation).

[290] Original quote in Portuguese: "Para mim é exigência da lei, manutenção da biodiversidade. Mas nao adienta, sao quadros isolados, "ilhas", sem conexão. Seria melhor que a exigência fosse que a RL encosta-se nas APP" [ITW n°025]

[291] Original quote in Portuguese: "É o ônus que estamos carregando. Deveria ser divididos com os demais. Porque você tem 80% fechado aqui e em Sao Paulo nao. To compreendo um edifício e deixando 80% sem nada? Os compradores vao ter que pagar. Vai ter um momento quando o consumidor vai pagar por isso. Queremos que nosso consumidor reconhece isso, que reconhecem no valor que temos o código florestal mais rigoroso. A APROSOJA trabalha nesse sentido nesse momento" [ITW n°027]

Finally, the *climate value* refers to the link made by farmers between the presence of forests and their benefits for either local climate (e.g. humidity, local/regional rainfall pattern) or global climate (i.e. regulation of greenhouse gases, carbon stocks). Only 12 farmers noted either of these possibilities, which I both coded under a same variable due to the ambiguity of the term "*clima*" in Portuguese, which can both refer to the local and global climate. Examples of farmers' statements for this category are: *"[the LR] helps keeping carbonic gas"* [ITW n°064], or *"[the LR] has a great influence on both local and global climate (...) it rains more because it is close to forests, therefore it rains more"* [ITW n°094]. Surprisingly, there were less producers recognizing a climate value to APPs and LRs than the number of producers recognizing local (20) and global (16) climate impacts when asked about deforestation.

What this analysis reveal is that producers attribute very distinct roles to the native vegetation present on their property, depending on their proximity with riparian areas. APPs are generally acknowledged for their role in water preservation while LRs for their role in biodiversity protection and climate regulation. Based on producers' answers, there seems to be an inverse relationship between the willingness to preserve and the distance from riparian areas. In the BR-163 region and the Chapada dos Parecis regions, riparian areas are usually densely forested and sandier than flat areas. It is however unclear whether landowners' discontent with LRs is more due to the extent of the conservation percentage or the fact that it prevents them to use some fertile soils covered with native vegetation. What casts the doubt on such a relationship is the difference in the way LRs and APPs are distributed between the two study areas. In the Chapada dos Parecis, APPs and LRs tend to be conflated with one another, the LRs providing an extra buffer to APPs. As interviewee n°35 put it, LRs are the "fat around the APPs" [ITW n°035]. In contrast, the APPs of the BR-163 region

tend to be much thinner and LRs tend to be concentrated in squares or patches that seem "randomly" distributed around the property.[292] If we assume the similarity in environmental perceptions and values of producers of both areas, then such a relationship would be proven wrong since we would expect the same type of landscape in both areas. If there may be some truth to this relationship, many were those who deforested sandy areas to plant regardless of soil characteristics.[293] It is therefore my opinion that it is hard to generalize such a relationship as others have, although there is truth to it. As one author put it:

> *"For example, soybean/corn producers will not deforest the riparian vegetation conservation areas because the Forest Code restricts such a practice but simply because of the natural low fertility and physical characteristics of soils (sandy soils) that require high investments that make agricultural production uneconomical. Thus, the preservation of riparian vegetation happened because the area is not recognized as suitable for agriculture" (Empinotti 2016: 17-18)*

I have not been able to further this analysis, but future research examining this relationship should attempt to overlay native vegetation data with soil quality data to see whether boundaries of sandy areas match with those of preserved native vegetation.

The utilitarian judgment made about APPs and LRs, and the dominant utilitarian nature of pro-environmental values held by soybean producers, demonstrate that the 'productivist' identity of these individuals is one of the most important analytical lens to explain the type of pro-environmental values they have. The fact that these pro-environmental values may be determined in great part by utilitarian consideration should not appear surprising to anyone. What may be more

[292] To be clear, I do not think these were randomly distributed. I am simply using this expression to convey an idea of how the two landscapes look different.

[293] One only has to look at satellite imagery of any region to see how APPs width vary from one land plot to another, reflecting significant differences in decision-making regarding land clearing.

relevant is to think about how such values may not have been present in the mind of producers at times when economic and biophysical conditions were different. In the early stage of colonization, for instance, when swaths of smallholder arrived in a mostly preserved frontiers, the presence and importance of these values may have been much less. Now that some soybean producers have large-scale operations and have secured significant wealth, post-materialist concerns are perhaps logically more prevalent. The content of those values, especially with respect to LRs, is also influenced by the way producers perceive societal pressures to conserve areas. Thus, the changes in context influencing the content of pro-environmental values may not have only to do with economic conditions. Other types of interactions with policies and society at large (affecting their identity of producers by "demonizing" them) also play a role and can be leveraged to improve preservation.

4. GOOD AGRICULTURAL PRACTICES: THE EMPHASIS ON SOIL HEALTH

4.1. METHODS & DATA

Producers were asked during the interviews to explain what a "good agricultural practice" (GAP) was. After asking the definition of GAP, I asked them to give me a definition of what a conservation practice is, in order to see if they were any differences. Finally, I asked producers to tell me what GAPs they were doing on their property. I made a point of not giving further direction to the interviewees who were asking for more explanation about what a GAP was. I simply said them to tell me what they considered to be "good" instead of referring to any list of good agricultural practices that may have been established by governmental body. Thus, this set of three questions were not designed to directly measure the adoption of a set of practices already defined informally by the researcher or officially by any relevant public institutions, contrary to many

studies about the adoption of GAPs (Vignola et al. 2010; Latawiec et al. 2017; Michel-Guillou and Moser 2006). Rather, following an ethnographic approach, the choice was made to let the farmers express their own views on what a good agricultural practices (GAPs) meant to them.

This methodological choice is motivated by correcting two important issues in GAP adoption studies. First, most studies examining the adoption of good agricultural practices "assume" the familiarity of landowners with such practices, which is often not the case. Surveys or semi-structured questionnaires tend to ask farmers directly whether they do practice X or Y. However, as past studies have demonstrated, many farmers are unfamiliar with the term "good agricultural practices" and what they cover. In a recent study about GAP adoption by cattle-ranchers in Mato Grosso, researchers demonstrated that as low as 12% of the interviewees were familiar with the surveyed GAPs (Latawiec et al. 2017). The uncertain knowledge about GAPs on the part of interviewees can lead to various measurement biases in identifying practice adoption, or counter-intuitive results regarding its related elements (obstacles to adoption, perception of practices, etc.), not mentioning the fact that GAPs may present major differences from one region to another. In their study, Latawiec at al. (2017) partly control for this issue by first asking whether landowners are familiar or not with good agricultural practices before beginning the survey questionnaire.

Second, farmers tend to over-report adoption when asked about whether they do particular practices, especially in Mato Grosso (EMBRAPA, personal communication). As the previous sections of this chapter have demonstrated, producers of Mato Grosso have been exposed to numerous requests from researchers of NGOs or research institutions looking to collect data from

them.[294] Since producers are conscious to have a negative environmental image partly resulting from these NGO research reports, they tend to respond strategically to questions, since they fear their answers may be used to formulate policies (especially environmental) which will go against their interests in the future. For example, when asked whether they respect the forest conservation requirements of the APP or LR, farmers will typically systematically answer 'yes' although it is not necessarily the truth. Some researchers at local research agencies have thus abandoned survey-type measurements of practices (i.e. close-ended yes/no questions) since it yields inconclusive results. For instance, when asking producers about whether they used integrated pest management (IPM) practices, respondents would almost all answer yes although their field observations tend to show that only a minority rely on such practices (EMBRAPA, personal communication).

In such context, relying on a set of three open questions to assess GAPs can represent a preferable option. While answering the first and second questions about defining GAP and conservation practices, producers generally outlined the dimensions that make up a GAP in their view. With the third question, producers provided me with information about the practices they did in their farms. Producers sometimes responded to the first and second questions by mentioning practices they were doing rather than giving general principles of GAPs or conservation practices. Furthermore, when asked about GAP, many producers considered conservation practices as part of such practices. In the analysis that follow, the category of GAPs encompasses both conservation practices and GAPs.

[294] Not to mention IBGE's agricultural census and the producers' own regional statistical institute, the IMEA.

4.2. RESULTS

4.2.1. What are GAPs in the mind of producers? What are conservation practices?

To a large extent, large-scale soybean producers' understanding of what good agricultural practices are define the sustainability priorities reflected in their production systems. Producers identified 11 different dimensions to GAPs, which can be regrouped under the umbrella of 5 broader dimensions: environmental, soil, production, labor, and legal dimensions (**See Figure 6.1**).

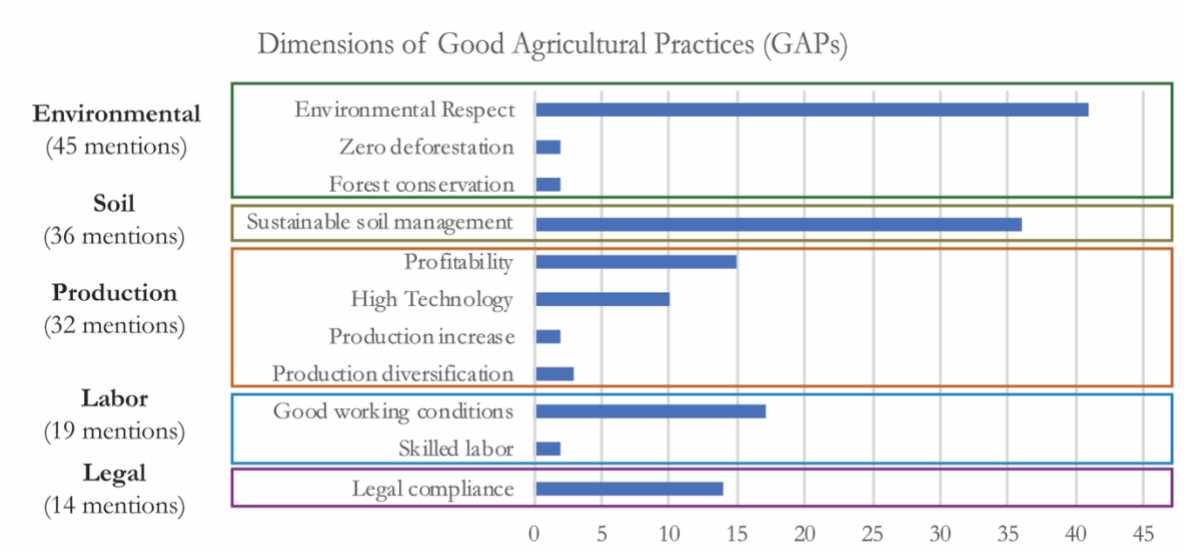


Figure 6.1. Dimensions of Good Agricultural Practices (GAPs) mentioned by the producers.

For landowners, GAPs are mostly identified with "respecting the environment" in a broad sense, often not specified further by the producers (45 mentions). This may cover a variety of aspects such as reducing water consumption, avoiding excessive use of pesticides, avoiding clearing of new forests, but also caring about the soils. This aspect was the second most identified by producers has to do with the soil (36 mentions), and was put in a category of its own as a result. Soybean producers emphasized over and over that soils were the most important parameter of production. Working with Cerrado soil has proven challenging for soybean farmers since the colonization times and, to a large extent, the story of successful agricultural production in the area

blends in with that of improving soil fertility. Producers thus emphasized the importance of "correcting" the soils for acidity, or to restore the soils with nutrients, something they started to do with the adoption of no till systems which is also the practice most identified with GAPs (see below the results for practices). Producers often referred to the fact that they are only temporary users of the soil stating that they only had the "usufruct" of the land ("usufruir da terra") (ITW n°012). As another interviewee put it: "You are not the owner of land, only a passenger, the property will belong to someone else in the future" [ITW n°015].[295] Soybean producers know that having soils that will be fertile in the long term is their best chance of producing well and much of the productivity increases depend on the quality and quantity of nutrients in the soils. It is therefore not surprising to see this aspect, essentially oriented toward production, ranking so high in their priorities.

Production concerns were the third most mentioned aspect of GAPs, highlighting the fact that such practices primarily serve the purpose of ensuring a better production. What does better production mean to them? Producers thought first in terms of profitability (15 mentions), use of high technology (10 mentions), production diversification (3 mentions), and production increase (2 mentions). Labor aspects was the fourth most mentioned aspect (19 mentions). Producers expressed the importance of ensuring good working conditions to employees as an important dimension of GAPs (17 mentions) with two producers underlining the importance of hiring skilled labor. Finally, the fifth most mentioned aspect was that of complying with laws (14 mentions), which can cover forest conservation laws, or agrochemicals-related laws, or labor laws.

[295] Original quote in Portuguese: "Tu não é dono da terra, só passageiro, a propriedade vai pertencer a outra pessoa no futuro" [ITW n°015]

These results show that producers may appear as having a "balanced" view of what the objectives of GAPs should be, at least if we consider that a "balanced" GAP should reflect the economic, social, and environmental dimensions of sustainable development. A good agricultural practice is therefore one that preserves the environment, preserve soils, and guarantees good working conditions while ensuring profitability. There is however some degree of overlap between the categories which makes it difficult to conclude whether one aspect clearly dominate others. It is difficult for me to know when producers mentioned "respecting the environment" as one of the dimensions of GAPs whether they meant the protection of biodiversity or the preservation of the soils. If it were the latter, then it would be easy to conclude that producers tend to favor GAPs that also make them earn money. Sustainable soil management practices can both be seen as preserving the environment but also as improving production and profitability. The question about conversation practices did not elicit many principles like the question on GAPs did. On the contrary, producers responded to that question by mentioning directly practices they were doing, such as no till or bench terraces. As a result, it is necessary to discuss exactly what type of practices they use and consider to be GAPs.

4.2.2. The GAPs used by soybean producers

Of the 104 producers in the sample, 99 shared information about the GAPs they were doing on their property. They identified 29 different GAPs and declared a total number of 349 practices. These practices cover a variety of dimensions, I therefore classified them based on what I believe were common objectives linking them with each other: (1) soil(-related) practices; (2) agrochemicals(-related) practices; (3) conservation(-related) practices; (4) production(-related) practices; (5) water(-related) practices.

Soil-related practices included the following practices: straw cover, bench terraces, contour planting, cover crops, crop rotation, micro-basin management. I excluded no till systems from this category because only 64 producers declared this practice as a GAP. I however know that in Mato Grosso, the overwhelming majority of producers (if not 100% of them) do this practice, especially in the study area. To prove this point further, I asked in another part of the questionnaire when they started this practice, and all of them answered with the date at which they started this practice (**See Chapter 5**). The fact that only 64 producers declared no till as a GAP may simply be due to their perception that no till is now a "common" practice and so it may not represent the "best practice" that one producer can do today.

All farmers practiced no till systems on at least part of their property. No till systems are generally composed of three different aspects: no tilling of the soil, cover crop (or straw) after harvest, and crop rotation. In Mato Grosso, however, farmers generally do not do the crop rotation part. They thus have a specific name their system since they know it is an incomplete no till system: "direct seeding on straw" (in Portuguese "*plantio direto na palha"*) (**See Figure 6.2**). Surprisingly only

11 farmers considered the generation of as much straw as possible as a GAP, although it is a key aspect of no till systems.[296] In order to increase the amount of straw on their property, which is insufficient despite the adoption of maize as a second crop (**See Chapter 5**), farmers have increasingly adopted cover crops for the interseason between June and October (21 farmers reported doing this). Having a cover crop helps increasing the organic matter in the soil and generate more straw (**See figures 6.3 and 6.4**). Despite being identified as a "good practice," no till systems in Mato Grosso rely heavily on glyphosate applications to kill weeds and would not have worked without it, according to a producer (ITW n°039).

Figure 6.2. Planting machine over non-tilled soil (maize seeding). Picture taken by the author in the BR-163 region (February 2017).

Only 12 producers reported relying on crop rotation. These producers were very specific about the meaning of "rotation" as opposed to "succession." Crop rotation is different than crop succession, which refers to double-cropping systems combining soybean and corn, or soybean and cotton within the same agricultural calendar year (only 9 producers declared doing crop succession

[296] This was counted as a separate practice because this may involve planting cover crops or additional grasses with the second harvest. Because soybean producers were not specific about it, however, I did not include this as a "cover crop" practice.

as a GAP). Producers relying on crop rotation, on the contrary, take some of their plots out of soybean production for one or more years and plant cover crops on them, and they calculate their benefits over multi-year time periods as opposed to many other farmers (**See diversification production strategy in Chapter 5**).

Figure 6. 3. Sorghum is typically used as a cover crop. Picture taken by the author on a private rural property in the Chapada dos Parecis region (June 2017).

Figure 6.4. Some producers rely at times on a mix of different cover crops and they use them for seed production. Picture taken by the author on a private rural property in the Chapada dos Parecis region (June 2017).

Producers are reducing erosion in areas with slope by doing terrace farming. Terrace farming refers to a series of practices ranging from bench terraces (i.e. changing soil topography to break up the terrain into successive flat terraces to reduce water flush speed) to contour farming (i.e. planting seeds running level around a hill, perpendicular to the terrain slope instead of planting lines up and down the slope) (**See Figure 6.4**). 26 interviewees reported at least one form of terrace farming, mentioning two practices: (1) "curvas de nível" which can mean contour plowing or contour planting; (2) "terraços em base larga" which refers to creating small "bumps" of dirt according to the slope level to slow down water runoff. The most advanced practice in this field, according to farmers, seem to be the management of micro-basins. This refers to the planning of soil topography in several properties in a given area (4 producers reported this practice as a GAP).

In Mato Grosso, these erosion-reduction practices went through some evolution because of the adoption of no till systems. ITW n°008 told me too that farmers had stopped doing bench terraces following the adoption of no till systems, starting in the mid-1990s. The perception was that the

straw cover left after harvest helped reducing soil erosion. However, as EMBRAPA indicates, this was not corroborated by any scientific studies and was also motivated by the easiness of seed planting, pesticides spreading and harvesting (Machado and Wadt n/a). Interviewee n°008 further told that there was a time when they used to do bench terraces, but the curve was so high that the harvesting machines could not go there (bench terraces would thus result in losing production areas). According to him, farmers now try to rely again on terrace farming with large base which ensures the erosion reduction while still allowing harvesting machines to pass over these areas. EMBRAPA indicates that this technique "has the advantage of allowing cultivation in almost all the area and facilitates maintenance with normal operations of soil preparation"[297] (Machado and Wadt n/a).

Another issue with no till systems is that, over time, soils tend to become compacted. Some producers explain that every 5 years or so, they have to use a machine to remove soil compaction to restore soil permeability. Only 5 producers reported this. From time to time, it is also necessary to add lime again (i.e. correcting the soil acidity). Producers periodically "correct" their soils for acidity and other nutrient deficiency they may present (11 producers reported this as a GAP).

[297] Original text in Portuguese "Têm a vantagem de permitir o cultivo em praticamente toda a sua superfície e de facilitar sua manutenção com as operações normais de preparo do solo."

Figure 6.4. Example of terrace farming technique with contour farming for rice cultivation in Goiás. Planting seeds running level around the hill help reduce erosion more than if the planting row was up and down the hill. Picture from Pedro Luiz O. de Almeida Machado (Machado and Wadt n/a).

With respect to practices related to the use of agrochemicals, most producers remained fairly vague and 34 reported doing a "correct use" of chemicals. I coded this category of "correct use" to cover all the statements made by farmers regarding the use of chemicals: reduction in the number and volume of agrochemical applications, selection of an accurate timing for applications, exclusive use of products approved by the authorities (Ministry of Agriculture), correct application of the manufacturer's instructions, and avoidance of chemical leaching (including not throwing away into the river the water used for cleaning equipment and machines). Only 21 producers reported the recycling of agrochemical packaging as a GAP although it is mandatory in Mato Grosso. Similarly to no till techniques, this may simply mean that this practice has been integrated by most producers and they may not consider it to be a "best practice" anymore. The correct disposal of chemicals is monitored locally by the INDEA and producers have to designate a specific area on their property in which packages are stored before disposal to avoid any contamination. ITW n°096 pointed out that 15 years ago producers used to burn all agrochemical

packaging somewhere in their property and burry it, which suggests that not a 100% of producers may be recycling yet.

Several practices relate to decreasing the use of agrochemicals. First, 10 producers shared the fact that adopting genetically-modified seeds such as Monsanto's Intacta ® variety helped reducing the number of pesticides applications they had to do. Second, 9 producers indicated using biological products for pest control or fertilization. For instance, there farmers may rely on swine or poultry manure for fertilization. Third, 8 producers reported using Integrated Pest Management (IPM) methods of controlling pests. According to the United Nations Food and Agricultural Organization (FAO), IPM can be defined as:

> *"the careful consideration of all available pest control techniques and subsequent integration of appropriate measures that discourage the development of pest populations and keep pesticides and other interventions to levels that are economically justified and reduce or minimize risks to human health and the environment. IPM emphasizes the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms" (FAO n/a)*

In practice, this means not only using biological pest control methods, but also monitor property plots on a regular basis with travelling teams of pest controllers ("*pragueiros*" in Portuguese). Many producers do not use this labor-intensive method because it would result in high costs given the sheer size of their property. Third, 5 producers mentioned relying on precision agriculture. Precision agriculture refers to advanced techniques of land-use and soil analysis (relying on satellite imagery, drones, information technology, and so forth) that allow to determine the variability of soil characteristics in a property, enabling producers to determine the optimal amount of inputs needed for each plot. This can help reduce the use of agrochemical fertilizers, this is why I classified it in the chemicals-related practices.

Turning to conservation practices, producers unsurprisingly mentioned Areas of Permanent Protection (APPs) (34 mentions) and Legal Reserves (LRs) (20 mentions) as GAPs although they are mandated by law. The fact that APPs are more frequently reported than LRs gives an idea of how farmers tend to agree more with the principle of APPs than that of LRs, which appear to them as an arbitrary and undue percentage of environmental protection. Only 7 producers reported the restoration of native vegetation as a GAP. Other practices reported by producers were: the prohibition of wildlife hunting on the property (3), the selective clearing of most fertile soils (3), the creation of ecological corridors for wildlife habitats (2), and the prohibition of fire on the property (1).

Producers indicated some production practices were GAPs. Among them, 15 producers reported crop-livestock integration (ILP, in Portuguese: "Integração Lavoura-Pecuária") systems. Only one producers mentioned crop-livestock-forestry (ILPF, in Portuguese: "Integração Lavoura-Pecuária-Floresta") systems as a GAP, which shows how limited the scope of ILPF is for large producers, as of today (Gil, Siebold, and Berger 2015; Gil, Garrett, and Berger 2016). The most common, ILP, consists to intertwine corn with grasses during the second harvest of the year so that, once the harvest is over, tall grasses remain and cattle can feed on them.[298] As written above, 9 producers considered double-cropping systems (crop succession) as a GAP, while 2 identified relying on credit and 1 identified relying on crop storage as GAPs. Irrigation was also reported as a GAP by 3 producers. However, interviewee n°003 shared the fact that producers seem very "divided" regarding the use of irrigation for crops. Although he had plans to do irrigation, another

[298] Meanwhile, the cattle is either in another land plot of the property or confined.

interviewee told me that he thought "immoral" to use irrigation in such a rainwater-rich region (ITW n°096).

The use of water is somewhat related to agrochemical use but was classified in a separate water-related practices category. Producers have traditionally relied on water from rivers to mix agrochemicals. However, their growing awareness about contamination risks have led some to use water from wells instead, to avoid contamination to rivers (3 producers reported this). Some producers further realized that there still was a contamination risk with the use of wells and started to rely on rainwater harvesting systems (4 producers reported this). Only 3 producers mentioned that they tried to generally reduce the use of water as much as possible, without specifying how.

In sum, the analysis of the GAPs adopted by soybean producers draws clarifies the picture to of GAPs drawn earlier when analyzing the principles underpinning GAPs (**See Figure 6.5**). It helps solving the discrepancy between the "discourse" about GAPs and what producers actually adopt in terms of GAPs. In the previous section, the most important dimensions of GAPs were respecting the environment and the soils, followed by production considerations. In this section, it is possible to observe the over representation of soil-related practices (producers declared 154 soil-related practices, excluding the 64 reports of no till systems) which confirm the importance attached by producers to soil quality. The second most reported category of practices had to do with agrochemicals (87 practices reported) while the third most reported was conservation practices (70 practices). This may mean that soybean producers think of the "respect to the environment" dimension of GAPs not only through the preservation of native vegetation but mostly through the correct and reduced use of agrochemicals on their property.

However, another interpretation is possible. I often heard during interviews that producers reduced the use of agrochemicals because it represented a cost to them. With regular increases in input costs that are often the key determining factor about whether farm operations are profitable or not (See Chapter 5), it is possible that the prominence of agrochemical-related GAPs has more to do with production costs optimization. Hence, it is unclear whether the reduction in agrochemical use is motivated by environmental concerns or costs reduction priorities. In contrast to the other practices, only 28 production-related and 10 water-related practices were reported.

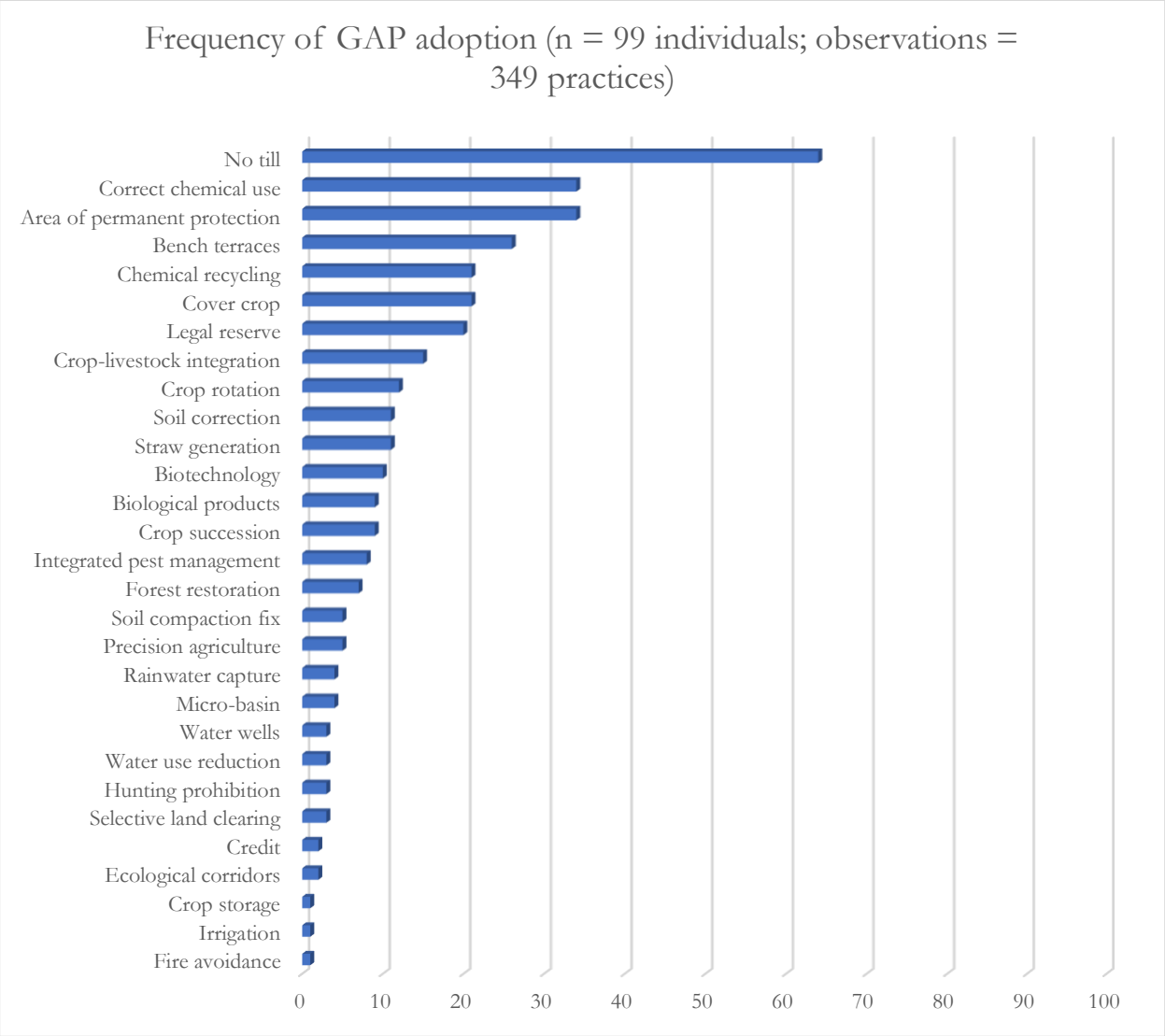


Figure 6.5. Summary of all the GAPs reported by 99 producers who shared data about their practices.

5. DO PRO-ENVIRONMENTAL VALUES INFLUENCE THE ADOPTION OF GAPS?

5.1. METHODS AND HYPOTHESES

The objective of this section is to analyze whether the adoption of good agricultural practices (GAPs) can be related to the fact that soybean producers attach importance to the ecosystem services provided by forests. To analyze this relationship under different angles, I defined different types of dependent variables (DVs) (**See Table 6.2**) which I test in separate statistical models. The first dependent variable defined is the number of GAPs adopted by producers (i.e. variable "GAPS sum") because it provides us with the greatest variation (and thus information) possible in the sample. I defined a second set of three different variables which corresponds to the groups of GAPs based on their common objective, as analyzed in the previous sections. There are 7 different types of soil practices, 6 of chemical practices, and 7 of conservation practices (**See Table in Annex**). Finally, I created a third set of three dependent variables to capture whether producers are doing at least one GAP within a category. This is a binary variable taking the value of 1 if a producer does at least one practice among the 6 or 7 of each category. The idea behind this last set of dependent variables is to see whether the relationship between pro-environmental values hold when we reduce the variation in the dependent variable. One reason for wanting to do so has to do with the way the data was collected.[299] Because I adopted a questionnaire format that let producers respond at their will to the question about GAPs, it is possible that a bias is introduced by the fact that the most "talkative" producers will declare more GAPs than others. As explained earlier, this may not have happened with survey-type questions where producers, but the problem would have been the "opposite" one, that of an over-estimation of what producers really do. Thus, having

[299] See the explanation on data-collection methods in section 4 of this chapter.

different levels of outcome variation captured by dependent variables encapsulating different degrees of GAP adoption helps correcting partly for the bias. For instance, when the DV represent the number of soil practices done by a producer, those with just 1 practice may be underrepresented as compared to the one doing 2 or 3 practices within this category (which skews the estimates given by the statistical model).[300] This problem is addressed in part with the binary DV representing a "Yes" or "No" depending on whether at least one practice in a given category is done by the farmer (giving a "1" value to producers doing soil practices, regardless of whether it is 1, 2, or 3). Different levels of dependent variable conceptualization help examining whether the relationship between pro-environmental values and GAPs hold when we modify the level of variation in the data.

The independent variables (IVs) correspond to the measure of pro-environmental values based on the questions covering the role of APPs and LRs on a property. Each time producers mentioned that such areas were important because they provided water, biodiversity, or climate ecosystem services, I coded "1" for marking the "presence" of this value in a producer's mind, and "0" in case of its "absence". These measures represent a simplification considering the wealth of qualitative evidence collected during the study period. However, it introduces less coder-related bias than if I had decided to code pro-environmental values making the synthesis of what all producers said. In the interest of clarity and transparency in the analysis, I decided to rely only on these two questions because they provided consistent results across the sample (i.e. producers mentioned the same ecosystem services) allowing for comparison between individuals. Results for this question were more homogenous than the ones I collected for the question on deforestation

[300] The maximum of soil practices adopted by one farmer in the sample was 3, although there are 7 different types of soil practices possible.

perceptions. At the risk of over-simplification, they represent an initial approximation to simplify a complex concept into a 0-1 binary measure, but resembles the interpretation of values made in other studies (Lamarque et al. 2014; Vignola et al. 2010; Klain et al. 2017).

The control variables (CVs) correspond to a series of socio-economic and other indicators measured during the interview. Since I was unable to collect data about income, I chose to rely on the total area owned by each producer as a proxy for wealth and capitalization (i.e. variable "Area"). I included the age of producers (i.e. variable "Age") as well a 0-1 measure of whether they got any education past high school (i.e. variable "Education"). Since producers followed a variety of academic training after high school, ranging from 2-years professional training in agriculture (i.e. "técnico agrícola" in Portuguese) to 5-years diplomas in law, economics, or agronomy, I included a 0-1 measure of whether the producer had been trained as an agronomist (i.e. variable "Agronomist") since it is fair to assume that they will have more agricultural knowledge than others. I included a measure of their time of residence in the area, which correspond to their time of arrival in Mato Grosso, to see if this had any influence in the degree to which producers may "care" about the land by adopting different types of GAPs. A variable measuring whether the landowners' property was in the Amazon was introduced to see if it influences the adoption of GAPs, especially conservation ones (like LRs or APPs) since there was more policy pressure in this biome. Finally, I asked every producer whether they had followed a professional training at the SENAR-MT (See Chapter 2). As a reminder, these trainings can as much cover GAPs as deal with some aspects of farm financial management or family succession. It thus represents a "limited link" with GAPs, but it measures the degree to which producers get informed about the latest agricultural practices better than if I had included a measure of

information based on the data sources they use. Chapter 2 indeed demonstrated that large-scale soybean producers are fairly homogenous in their access to diverse sources of information (i.e. there is little variation among individuals in the sample). **Table 6.2.** provides descriptive statistics on all variables used for the analysis.

Descriptive Statistics					
Variables	**N**	**Mean**	**St. Dev.**	**Min**	**Max**
Dependent variables					
GAPs sum	99	2.88	1.73	0	7
Soil practices (count 0-7)	99	0.91	1.01	0	3
Chemicals practices (count 0-6)	99	0.88	0.86	0	3
Conservation practices (count 0-7)	99	0.71	0.90	0	3
Soil practices 0-1	99	0.55	0.50	0	1
Chemicals practices 0-1	99	0.60	0.49	0	1
Conservation practices 0-1	99	0.44	0.50	0	1
Independent variables					
Water value	99	0.81	0.40	0	1
Biodiversity value	99	0.51	0.50	0	1
Climate value	99	0.12	0.33	0	1
Cumulative values	99	1.43	0.74	0	3
Control variables					
Area (100ha)	99	97.90	136.04	0.00	750.00
Age	99	49.41	12.81	27	78
Time of Residence	99	30.21	9.48	1	62
Amazon Biome	99	0.16	0.37	0	1
Training	99	0.49	0.50	0	1
Education	99	0.49	0.50	0	1
Agronomist	99	0.19	0.40	0	1

Table 6.2. Descriptive statistics of the variables retained for the analysis.

In order to test the relationship between GAP adoption and independent variables, I developed a series of statistical models to refine the statistical estimates and accuracy. For each model, I added independent variables by groups in order to detect any inconsistency in model building. In the first model (Model 1), I tested the DVs by only adding the pro-environmental values. In the second model (Model 2), I added socio-economic variables to the model, minus the "agronomist" variable as I suspected that some interaction existed between this variable and the "education" variable (i.e.

all agronomists are educated). In the third model (Model 3), I took out the "education" variable and added the "agronomist" variable. Finally, in the fourth model (Model 4) I included both the education and agronomist variables to the model. I tested the following dependent variables separately using the same models (**See Annex for the results tables for each dependent variable**):

- DV 1: Adoption of GAPs in general
- DV 2:
    - DV 2a: Adoption of Soil-related practices (sum)
    - DV 2b: Adoption of Chemicals-related practices (sum)
    - DV 2c: Adoption of Conservation-related practices (sum)
- DV 3:
    - DV 3a: Adoption of Soil-related practices (0-1)
    - DV 3b: Adoption of Chemicals-related practices (0-1)
    - DV 3c: Adoption of Conservation-related practices (0-1)

Finally, I was interested in seeing whether the accumulation of pro-environmental values for a same individual would increase the likelihood of adoption. I therefore ran a series of tests for DV 1 and DV 2, following the same models, but replacing the three distinct pro-environmental values by a variable representing the number of pro-environmental values each individual holds (i.e. variable "Cumulative Values") with a score from 0 to 3.

For the DVs that represent count variables (non-binary variables), I opted for a Poisson regression analysis because the Poisson distribution better represents count outcomes such as the number of practices adopted (Long and Freese 2014).[301] For binary DVs representing Yes-No outcomes I ran a logistic regression. The coding of the variables and descriptive statistics were made with Microsoft Excel 2016 and all statistical analyses were all conducted with RStudio version 1.1.419.

[301] Such regression models are usually used to analyze the number of accidents according to the day of the week, or the number of suicides .

The correlation matrices between these variables used for analysis as well as additional variables available in the dataset (such as municipal location of the properties) are available in the **Annex.**

The hypotheses of analysis are grounded in the observations made through fieldwork and the qualitative analysis. Because the soybean producers in the sample are large-scale landowners sharing a similar background, I expect any socio-economic variables to not be related (or limitedly so) to the adoption of GAPs (H1), contrary to what the literature or the common sense would generally assume (Prokopy et al. 2008; Baumgart-Getz, Prokopy, and Floress 2012; Edwards-Jones 2006a). Second, because I found that producers have different environmental perceptions and values, I expect pro-environmental values to influence the degree to which producers adopt GAPs (H2). Finally, following this reasoning, I would expect producers who hold more than 1 pro-environmental values to be more likely to adopt GAPs (H3). I present in the next section the results of this statistical analysis.

5.2. THE LIMITED, BUT SIGNIFICANT INFLUENCE OF PRO-ENVIRONMENTAL VALUES ON BEHAVIOR

5.2.1. The climate value influences positively the adoption of GAPs, but other pro-environmental values do not

General and type-specific adoption of GAPs (sum)

	Dependent variable:			
	GAPs (1)	Soil (2)	Chemicals (3)	Conservation (4)
Intercept	**0.88****	**-3.06*****	**1.20***	**0.25**
Water	-0.16	-0.02	-0.22	-0.49*
Biodiversity	-0.07	0.08	-0.07	-0.44*
Climate	0.35*	0.24	0.05	0.92**
Area (100ha)	0.001*	0.0005	0.001	0.001
Age	-0.01	0.03**	-0.02**	-0.02
Time Residence	0.01	0.03**	-0.01	0.01
Biome	-0.17	0.42	-0.17	-0.99**
Training	0.30**	0.99***	0.26	-0.15
Education	0.36**	-0.11	0.20	1.07***
Agronomist	-0.35**	0.41	-0.49	-0.75**
Observations	99	99	99	99
Log Likelihood	-180.43	-113.98	-108.80	-99.16
Akaike Inf. Crit.	382.87	249.97	239.59	220.32
Note:				*p<0.1; **p<0.05; ***p<0.01

Table 6.3. Comparison of the effect of pro-environmental values on the general and type-specific number of GAPs adopted by producers using Poisson regression models. The p-value thresholds are indicated on the table. Dependent variable (1) corresponds to the number of GAPs adopted by a producer across all categories. Dependent variables (2), (3), and (4) refer to the number of soil-related, chemicals-related, and conservation related adopted by a producer, respectively. **Interpretation:** Since it is a Poisson regression model, we have to interpret the exponential value of the coefficients (which are based on a logarithmic function). For example, using the GAPs model, for any standard change of 1 unit in the climate value, the expected count of GAPs change by a factor of $e^{(0.35)} = 1.41$. Therefore, in an theoretical way, we could interpret as the following: "if a producer that has adopted 2 GAPs was to attach importance to a climate regulation role of APPs and LRs (climate value = 1), she would likely adopt 2 x 1.41 = 2.82 practices."

The analysis of the influence of pro-environmental values over the adoption of GAPs yields interesting insights into the environmental behavior of producers **(See Table 6.3. and tables 6.d to 6.p in Annex).** Confirming our first hypothesis according to which socio-economic variables do have not much influence on adoption, the association between the area and age variables is

limited in terms of magnitude and statistical significance. The area variable is only statistically related to the adoption of GAPs in general, but not to specific types of GAPs. The age variable seems to be mostly influential for soil-related and chemicals-related practices. The education and agronomist variables seem to be relatively more important. Both variables are statistically significant in the case of adoption of GAPs in general and conservation-related GAPs. They are neither associated to soil-related nor to chemicals-related practices. The effect of these variables is however ambiguous since the agronomist variable tend to cancel out the effect of the education variable. In sum, reviewing the first hypothesis according to which socio-economic variables do not matter for the adoption of GAPs, it would appear that the age and area owned are not important factors in whether producers adopt practices or not. The education level of a producer seems to matter more, but the fact that this effect is reduced when the producer is an agronomist tend to limit the strength of this result.

Turning to the main independent variables of interest, it appears that the effect of pro-environmental values on adoption is quite limited for the adoption of most GAPs. The fact that producers attach importance to the water and biodiversity services provided by APPs and LRs does not seem to influence their adoption of GAPs, soil-related GAPs, or chemicals-related GAPs. It only affects the adoption of conservation-related practices, in a negative way which is fairly counter-intuitive since one may expect producers sensitive to water and biodiversity to adopt *more* conservation practices. 34 producers indeed mentioned Areas of Permanent Protection (APP) as a GAP practice while 81 farmers mentioned that the role of APP was to preserve water.

The fact that producers attach an importance to the climate regulation properties of forests seem to positively influence the adoption of conservation-related practices, but not other types of practices (except GAPs in general). Given the low number of producers who declared valuing this aspect (only 12 did so), this result tends to support the idea that those who believe in the climate change impacts of a preserved landscape tend to be the most progressive and proactive in terms of environmental conservation. As pointed out earlier, it is surprising that less producers valued the climate regulation benefits of APPs and LRs although they were more to acknowledge the role of deforestation (and consequently, forests) into the local (20 producers) and global climate (16). One explanation to this is that recognizing the role that forests play in regulating climate is a double-edged sword for farmers. On the one hand, some farmers perceive changes in rainfall patterns over the short-term when large tracts of forests are cleared nearby their farms, or in the long-term, based on their time spent on their farm as they have witnessed most of the clearing history of the area. On the other hand, they are conscious that making such a link publicly would (1) make them 'guilty' of greater environmental damage than they already are deemed responsible for in the eyes of the public (i.e. deforestation) (2) make them liable for even a broader array of ecosystem services for which they are not compensated at all, while also turning future prospects of clearing some additional vegetation dimmer. This makes recognizing the importance of APPs and LRs for climate change a less widespread and socially accepted environmental value.

Some control variables had an important effect on the adoption of GAPs by producers. Among them, the association between training (i.e. farmers who have followed a training with the SENAR-MT) and GAP adoption seem to be correlated at the 5% level for both GAPs in general and soil-related GAPs. This result makes limited sense when examining the content of the trainings offered

by SENAR-MT. On the one hand, some trainings are about pesticide application practices (but those tend to be followed by employees more than landowners), on the other most are about farm management aspects such as labor regulations, farm accounting, family succession. This variable may instead capture something else than the training content. Producers following a training at SENAR-MT tend to be the curious ones, those who want to improve their current practice by getting professional information. As a result, even though producers in the sample did not follow trainings especially about GAPs, the fact that they get their information from the SENAR-MT and that they are *looking for* information makes them innovative producers.[302]

The length of time spent in the region seemed to be limitedly related to GAPs as it was statistically significant at the 5% level only for soil-related practices. Finally, a last surprising result was that producers located in the Amazon biome (16 producers) tended to adopt less conservation-related GAPs than producers located in the Cerrado biome. This may indicate that producers in the Amazon biome (interviewed in Sinop) have a more reactionary relationship with the environment, perhaps because they were more exposed to policy enforcement than those in the Cerrado. They may perceive the protection of LR or APP not as a GAP but as a "legal burden."

The statistical models testing the relationship between the adoption of at least one type-specific GAPs and pro-environmental values all confirm the same results (**See tables 6.h to 6.j in Annex**). These results are therefore robust even if we reduce the variation in the dependent variable. This

[302] I developed this interpretation of this particular variable effect as a result of a meeting with SENAR-MT officials, a year after the data-collection for this dissertation. I met with a few members from APROSOJA-MT, SENAR-MT, and IMEA on May 2018. After presentation of my results, I exposed to them the fact that producers who followed SENAR-MT training were more likely to adopt GAPs. They replied to me that they would "like to think" it is true, but what they observed was more that those who come for a training are already innovative producers, adopting GAPs, in search for more information.

indicates that the results were only limitedly affected by the design of the interview question and that the variation in GAP adoption due to the most talkative producers do not bias the results. The statistical models testing the influence of pro-environmental values when they add on to each other (cumulative values) yielded inconclusive results (**See tables 6.k to 6.m in Annex**). I am therefore not able to confirm my third hypothesis.

5.2.2. Do pro-environmental values conflict with other imperatives, or are they simply part of an environmental discourse?

Overall, this exploratory logistic statistical analysis of the influence of pro-environmental values on the adoption of GAPs by elite, large-scale farmers of Mato Grosso has shed light on an overlooked aspect of farmer behavior. The hypotheses were limitedly confirmed, and I am not able to reject the associated null hypotheses for all of them (**See Table 6.3, and tables 6.d to 6.p in Annex**). Here is a summary of the results organized by hypotheses (**Table 6.4**):

Hypotheses	**Results**
H1: socio-economic variables do not influence adoption of GAPs	Area owned limitedly influences general GAP adoption Age limitedly influences Soil- and Chemicals related GAP adoption Education and Agronomist influence the adoption of general and Conservation-related GAPs
H2: pro-environmental values influence the adoption of GAPs	Water value and Biodiversity value do not influence the adoption of general, Soil-, and Chemical-related GAPs. They influence negatively the adoption of Conservation-related GAPs. Climate value influences the adoption of general and Conservation-related GAPs, but not Soil- and Chemicals-related GAPs.
H3: the accumulation of pro-environmental values influence the adoption of GAPs	Cumulative values do not influence the adoption of general, Soil-, Chemicals-, and Conservation-related GAPs

Table 6.4. Results of the statistical tests of the influence of pro-environmental values on GAP adoption.

This statistical analysis presents some obvious limitations due to sample size (less than a 100 producers), the specific population (i.e. only large-scale producers), location (largest soybean producing municipalities), and its cross-sectional nature (one time period). In that context, further statistical refinements would bring about only limited additional insight. For instance, running the

models using negative binomial regressions instead of Poisson regressions did improve the statistical significance of most predictors but did not fundamentally changed the interpretation of the effects. Hence, I focus more on the theory-building insights that such an exploratory statistical analysis provides in combination of the qualitative evidence collected.

The reason for the overall non-association of pro-environmental values with GAPs related to soils or the use of agrochemicals has perhaps to do with the fact that, contrary to conservation practices, those practices are directly linked to the profitability of the farm. Most soil-related GAPs have a direct impact on soil fertility and therefore on yields, while most chemicals-related GAPs will end up saving money to producers since they will spend less on agrochemicals for controlling pests. This would indicate that pro-environmental values might be more closely related to GAPs which effect is to directly preserve the environment. These observations are consistent with the social psychology literature which emphasize the importance of relating specific values or attitudes to the behaviors they correspond to. Some authors report that some studies "even showed a negative relationship between *specific* self-reported environmental behavior (curb-side recycling" and a *general* pro-ecological attitudes)" (emphasis added by the author) (Fransson and Gärling 1999: 373). The lack of significant correlation or counter-intuitive correlation may also come from measurement specificity problems (Prokopy et al. 2008).

On the other hand, the fact that water and biodiversity values tend to be negatively correlated with the uptake of conservation practices is puzzling and raises two key questions. First, given the high number of farmers with water and biodiversity values, is there an "environmental discourse" of farmers that may not be followed through by much action? Second, could it be that pro-

environmental values conflict with other characteristics of landowners, resulting in the non-adoption of conservation practices even for producers who value these aspects. I return here to the fact that, despite judging APPs and LRs important for the environment, many producers criticized the latter areas and complained about not being able to produce crops on part of their LRs. This interpretation is somewhat reinforced by the fact that producers in the Amazon biome tend to be less keen on adopting conservation practices, perhaps because they were the most frustrated by environmental restrictions in the 2000s, when the federal government cracked down on deforestation right at the moment they heavily deforested to plant soybean (**See Chapter 4**).

This "disconnect between what people say and do" is well known of the social-psychology literature, which points out that: "Some of the obstacles to behavior change include the direction and strength of attitudes, insufficient individual capabilities, social norms and cultural beliefs, incentives or disincentives, and structures such as laws, regulations, technology, and the broader socioeconomic and political context" (Saunders, Brook, and Eugene Myers 2006: 703). I was able to observe this discrepancy between discourse and practice in the last section, with the difference between how producers describe what GAPs are (emphasizing environmental concerns) and what they actually do (adopt overwhelmingly more soil-related practices). The effects found in the present statistical analysis bring only a piece of the explanation of the environmental behavior of producers. Therefore, in the next section, I propose a conceptual framework modelling the relationship between environmental values, perceptions, and behavior for soybean producers to put the pieces of the puzzle together.

6. A MODEL OF ENVIRONMENTAL PERCEPTIONS, VALUES, AND BEHAVIOR

Given the importance of environmental perceptions and values in the land-use behavior of large-scale soybean producers, and based on the qualitative and quantitative evidence reviewed so far, I outline the elements of a model explaining the interconnections existing between these three elements over time. In this model, I assume that pro-environmental values, *defined here as beliefs about the positive role (e.g. ecosystem services) of particular environmental objects for utilitarian ends (i.e. benefits to human activities) or for their own sake (i.e. intrinsic),* influence one individual's perception of the environment, which in turn influence their actions. The results of these actions, if they modify the landscape, acts in a recursive way on perceptions, which in turn may inform a change in environmental values or the emergence of new values. The most trivial example of this is when individuals start valuing the forests after having cut down most of it. Therefore, the producers' interpretation of their past values, perceptions, and behavior is subject to some degree to retrospective evaluation. This means that what they think now has pushed them to stop deforestation (i.e. caring for trees) is different from what really made them stop deforesting at the time the behavior happened (e.g. possibly environmental policies, dire financial conditions, changing market conditions, and so forth). I partly remedy for this by including in the model perceptions about the economic and policy conditions and show how they too have influenced behavior.

I sketch below a conceptual model (**See Figure 6.6**) of how values, perceptions, and behavior may have interacted for soybean producers over the course of their residence in Mato Grosso. This model is a coarse generalization, and -of course- does not represent the diversity of individual behaviors. Producers are an heterogenous group of people with different characteristics and values,

therefore there may be some individuals who never attributed much importance to the environment and others who valued it significantly. It is also an ideal model in the sense that some elements in the model, like climate values, may influence behavior although the analysis made clear that only a minority hold such values. What this model therefore shows is a tentative theory framing of the paths leading to the evolution of environmental behavior and their interaction with values.

In this model, the starting point is the arrival at the frontier of these producers (1970s-1980s). When they arrived, these landowners carried with them (or not) pro-environmental values inherited from their personal history in the South of Brazil, and possibly learned through their relationship with the environment while running agricultural operations there. During this "arrival stage," the interviewed farmers emphasized that they already cared about the importance of water and forests (either because they had preserved them in the South, or seen the impacts resulting from their clearing). However, once in Mato Grosso, their perceived native vegetation (a biophysical environment a mix of forests and Cerrado areas) as abundant. Their need to develop agricultural activities, and the lower costs of doing so in the Cerrado areas led them to clear non-forest Cerrado vegetation areas first. Contrary to cattle-ranchers who preferred to clear riparian areas for letting cattle drink water, farmers did not clear these areas immediately because it was more work than for Cerrado areas, and not because these areas were sandier (farmers did not know this at the time, this is why some cleared areas for their farm headquarters near the rivers at first). They however quickly start perceiving that these areas had low soil fertility in a matter of a few years.

In a second phase of frontier consolidation (1990s to abour 2005), when much of the Cerrado (and some forest) areas had disappeared, their perceptions had changed. They realized that only

forests remained, which may lead them to value such vegetation type more. However, the rising profitability of soybean agriculture also turned forest clearing, prohibitively costly in the past, into an attractive investment, which conflicted with the importance (if any) they attached to forests. This resulted into the clearing of forest cover, primarily occurring in the mid 1990s and early 2000s in the study area. They nonetheless spared APPs mostly, because of their newly-acquired perception that soil fertility was low (this is especially the case in the Chapada dos Parecis region). Such extensive deforestation was also possible because of the low policy monitoring and enforcement at the time.

In a third phase of post-frontier (from 2005 up to today), the perceived scarcity of forests and total absence of non-forest Cerrado vegetation led them to revisit their environmental values and develop new ones. This scarcity of vegetation has been linked by some to perceived changing rainfall patterns, which made them recognize the importance of vegetation cover in (at least local) climate-related ecosystem services: the regulation of local and regional rainfall patterns as well as the generation of greenhouse gases and global consequences of climate change. This perception was reinforced by the heightened enforcement of environmental policies starting in 2004 with the PPCDAm and the fact that landowners in the Amazon biome (not so much them) experienced large-scale police operations shutting down sawmills (e.g. in Sinop) or putting rural properties under embargo. The private sector, through the Soybean Moratorium further increased pressure on soybean producers. In addition, after being struck by an important financial crisis in the 2004-2005, producers increasingly perceived that their production model needed to change toward intensified and vertically integrated systems. In that context, the reduced need for extra land caused by this shift in strategy made it possible to increase the coherence between their environmental

values and actual behavior. Producers stopped clearing additional land although they still have forest cover, and a few of them started reforestation activities.

This model shows what the articulation between values, perceptions and local outcomes may have been. The interest is less to know "how to prevent deforestation" than to show how outcomes such as deforestation reduction may have relied on a subtle articulation of perceptions of economic opportunities (new production strategies) and perceptions of changing institutional context such as perceptions of environmental policy enforcement elsewhere, and perceive changing market conditions with the Soybean Moratorium which goal was to shut down market access to deforesters.

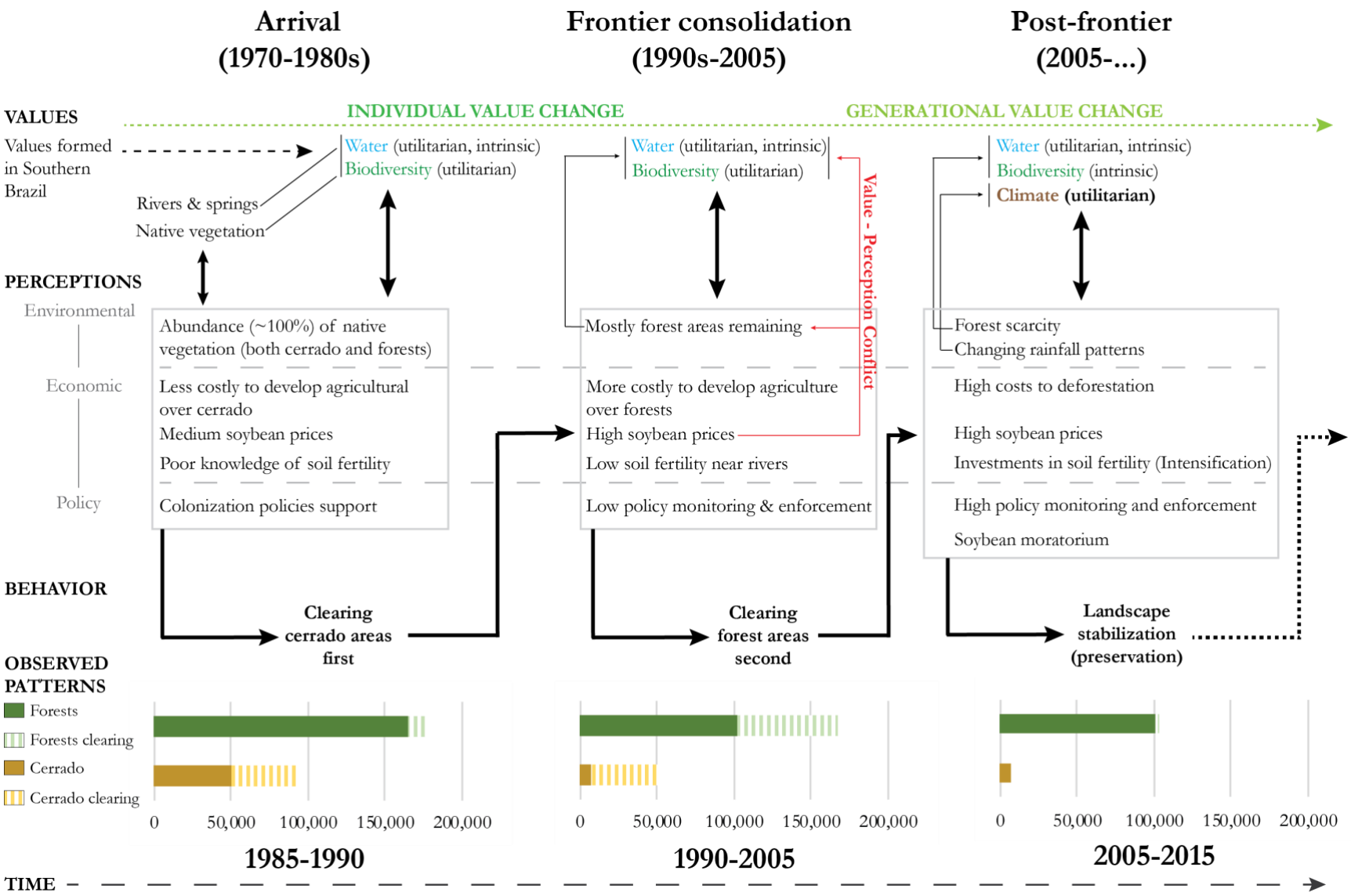


Figure 6.6. Conceptual model representing the evolution of environmental values and perceptions over time in the study area. Cleared area at property-level is in hectares (ha)

7. CONCLUSION

This chapter set out to answer the hardly answerable: how do environmental values shape perceptions and behavior, and how may these two elements influence, in turn, how individuals form values? The examination of the perceptions of deforestation impacts has revealed that the environmental perceptions of large-scale producers had much to do with the way they characterize what it means to be a 'good farmer.' This identity based on a "productivist" behavior find its roots in the producers' own definition of how one should legitimately use the land, in opposition to other categories of land-users such as cattle-ranchers, miners, loggers. They derive a great sense of legitimacy (of their land-uses) and social prestige from this identity of producers, and this partly stems from the fact that they judge their action as environmentally responsible, although this seems to be very much driven by utilitarian considerations.

This transpired their analysis of deforestation impacts, the negative aspects of which were minimized by producers by using an environmental rhetoric based on caring for soil health and fertility, and by almost exclusively recognizing local not global impacts. It is therefore not about production alone, but about producing "well", by caring for the soil, diminishing the quantity of agrochemicals used, and so forth, as the analysis of GAPs has shown. At the same time, the low percentage of individuals perceiving that deforestation was the "only way" to be profitable indicate that this identity has shifted from the pioneer one of the early stages of colonization of the frontier ("desbravadores") to one where success is assessed based on a producer's entrepreneurship skills. Although they do not exclude having to deforest again in the future to ensure the availability of enough cropland to new family members entering the activity, producers emphasize the necessity of relying on advanced agricultural technology and improving farm management to get a profitable

farm. Expanding is simply not enough anymore, and producers have a large variety of variables to tackle if they want to run a successful farm operation. In this context the environment is not an obstacle anymore, but something that simply needs to be "managed" or "dealt with," and the terms of its protection can be questioned based on this rhetoric of responsible producer. This self-identity (Burton 2004a) thus partly explains why the pressure on the environment has reduced.

Pro-environmental values are part of this self-identity, and the way it interacts with perceptions and behavior was highly dependent on the changing context of soybean production areas of Mato Grosso. It would seem, based on the regression analysis, that those who developed over time a sensitivity for the climate regulation services provided by forests (climate value) have been more keen on adopting GAPs and more specifically conservation practices. Yet, when discussing the role of pro-environmental values, there will always be a discrepancy between discourse and practice, which has been demonstrated several times throughout the chapter with (1) the different between GAP definition and the practices adopted; (2) the fact that producers with water and environmental values would tend to adopt *less* conservation practices. The conceptual model outlined at the end of the chapter intends to summarize these interactions, while bearing in mind that it intends to explain how environmental values may have evolved for the subset of large-scale soybean producers, not for the whole soybean frontier of Mato Grosso. It sheds light on the fact that the current behavior and thinking of soybean producers is the result of a subtle balance between several factors. Although if market, policy, or technological conditions change, it is unsure whether this balance remain, it already has remained as such since soybean producing regions recovered from a major economic crisis in 2004-2005.

Conclusion: Toward sustainability?

"How do I know what I think until I see what I say?"
Attributed to ***E.M. Forster***

What lessons can be drawn from the expansion of the soybean frontier in the Amazon-Cerrado transition areas of Brazil for other commodity frontiers? This dissertation has discussed to a large extent the environmental impacts of this expansion, and how such impacts are mediated by market conditions, environmental policies, and the production strategies and environmental values of large-scale soybean producers. It has however limitedly dealt with other aspects, such as the significance of the soybean supply chain for Brazil's economy or the contribution of the soybean sector to job creation and development. It has also left out (intentionally) other members of the soybean supply-chain such as small and medium producers, associations, banks, government bodies, and so forth.

This dissertation has brought a new look into a population that many may consider as 'dominant' but who once were not. It documented the historical experience of smallholder colonizers from southern Brazil who came to Mato Grosso in hopes of a brighter future for their family. By describing their colonization history, their experiences and hurdles of the early stages, as well as their thoughts today, I hope to have brought a new understanding of who large-scale soybean producers are. Despite the limitations inherent to a research design focusing on large-scale producers and their environmental behavior, my hope is nonetheless to have given here a picture of this population of farmers that many will find accurate, or at least thought-provoking. To the farmers, my wish is to have transcribed their thoughts and experiences in an authentic and trustworthy manner. My long discussions with them were, by far, the most enjoyable part of this

research project and one of the experiences I appreciated most as a human being. Although this dissertation is intended to be relevant to all, I hope it will constitute an invitation for self-reflection to these producers, something they have always managed to do to by constantly evolving production systems when faced with the challenges of the frontier.

I opened this inquiry with a question: What explains the evolution of the environmental behavior of large-scale soybean producers? Given the breadth and ambition of this social sciences research question, I believe that I owe the reader of this dissertation a summary of the findings, especially after 6 dense chapters. Specifically, one may wonder: "how can he claim to have understood anything about how farmers adopt different behaviors?" While I make no such grand claims, I will outline some of my thoughts about how farmers evolve in a complex decisional environment composed of biophysical constraints (and opportunities), technological change, market conditions, institutions, and personal values. I hope this will help forming the basis of future research questions and inquiries more attuned to the complex reality of human-environment interactions. Some farmers may think that farming is easy, after all, but those who do not did not stick around to share their thoughts.

I organized the inquiry keeping in mind the work of Elinor Ostrom who – together with her numerous colleagues – believed that frameworks of inquiry such as the Institutional Analysis and Development (IAD) or Socio-Ecological Systems (SES) frameworks could provide common interdisciplinary frameworks that researchers from different perspectives and disciplines could use to learn from each other's cases. By relying on the Combined IAD and SES framework (CIS), developed by Daniel H. Cole, Graham Epstein, and Michael D. McGinnis, this dissertation will

add to many others contributing to understanding the complexity of human-environment relationship (Cole, Epstein, and McGinnis 2014, 2019). Although I have never used the word "commons" in this dissertation, I nonetheless wonder: is there something that is not, to some extent, a "common" on this planet? It makes no doubt to me that social sciences research should evolve toward more interdisciplinary and complexity, rather than the (surprising?) counter-tendency that one can often witness in academia.

Discussing the evolution of the environmental behavior of large-scale soybean producers, to give an accurate picture, requires a back-and-forth between multiple variables, at different scales, but also different processes and patterns. The CIS allows to make this interpretation while keeping track of many elements simultaneously. The patterns and processes (i.e. action situations) most examined in this dissertation were those by which producers cleared land and made decisions about agricultural practices or conservation practices. Such action situations are 'adjacent' in the sense that they often happened simultaneously or sequentially (i.e. one after the other, or the reflection about one fed the thought process related to the other) (McGinnis 2011).

I therefore propose here a conceptual model based on this framework that allow the interpretation of environmental behavior changes by producers. I will summarize below the chapters of the dissertation by singling out their contribution to understanding how Mato Grosso's large-scale soybean producers have managed their relationship with the environment for more than 30 years. I will use each chapter's takeaways to fill in the boxes of the CIS framework in a series of figures that represent the evolution of action situations, by keeping the focus on land clearing as the central process and behavioral outcome. These figures will represent (1) the transition of large-scale

soybean producers from the early stages of the colonization (starting in the late 1970s) to before the great acceleration of soybean production in the 1990s (**Figure 7.1**); (2) the expansion of soybean production under the impulse of global markets to the soybean crisis of 2004-2005 and heightened environmental policy enforcement of 2004 (**Figure 7.2**); (3) From the mid-2005s to today, after the revision of the Forest Code (FC) (**Figure 7.3**). **Figure 7.4** details the evolution of action situations across the three periods, and illustrate how each period "feed forward" the next. After the summary of the chapters, I will summarize, using this last figure, my interpretation of how and why have producers changed of environmental behavior over time.

1. Lessons from Mato Grosso

1.1. Technological and institutional conditions: necessary but insufficient conditions for colonization (Chapter 1)

In chapter 1, I argued that the colonization of the Amazon-Cerrado transition area of Mato Grosso occupied a unique place in the westward colonization history of Brazil. I tried to understand specifically why the group of large-scale soybean producers chose to settle on two plateaus of Mato Grosso (i.e. the Chapada dos Parecis and the BR-163 region). In particular, I inquired: what were the conditions (institutional, economic, biophysical, …) explaining why colonizers chose these two plateaus specifically, and how much can these initial conditions explain their success?

I demonstrated that, until the end of the 1970s, these areas were stuck in between two distinct fronts: the expansion on the Cerrado(s) of the Center-west on the one hand, and the creation of colonization "islands" based on perennials, rice, mining, and cattle-ranching to the North. Although the colonization of land was "technically possible" since the *lei das terras* of 1850 which authorized the spontaneous settlement on Brazilian public lands by anyone (*posse)*, by the 1930s

not a large portion of the Center-West and North region of Brazil had been colonized (at the exception of rubber areas in the Amazon). The westward colonization of Brazil was "triggered" by the federal government starting from the 1930s with the March to the West (1937) for the Cerrado and later with the creation of the SPVEA in 1953 for the Amazon. In the Cerrado, the federal impulse took mostly form with the creation of colonies of smallholders (CANs) which were spotty colonization settlements oriented toward agriculture.

In Mato Grosso, the federal initiatives impacted long-standing, but mostly failing, state-level colonization initiatives. The state had already but unsuccessfully taken advantage of the flexibilization of land tenure laws permitted by the 1850 *lei da* terra. Until the arrival of the military regime in the 1960s, the state-led colonization was limited to offering large areas of land to wealthy investors or consisted of tiny land donation to sporadic spontaneous settlers. In the 1950s, amendments to the 1949 state land code permitted the sale of large areas under state jurisdiction to individuals and private colonization firms (*colonizadora*). Despite a few *colonizadora* projects in the northern part of Mato Grosso (forests within the Amazon biome) centered around cattle-ranching and various agricultural uses, the instability of tenure due to land speculation (the land was often sold multiple times to different owners) and widespread corruption in state land agencies resulted in limited colonization progress (and migration) by the time the military regime took power in 1964. The private colonization model of the *colonizadora* nonetheless found its source in that period, a factor that will be determining for the colonization of the Cerrado areas of the BR-163 and Chapada dos Parecis region.

The arrival of the military changed this. Armed with a geopolitical vision that commands the occupation of the western and northern areas of Brazil, the federal government created development programs and associated federal agencies to fund the expansion of agricultural and cattle-ranching, offered tax incentives, and added infrastructures achieving the connection of the Amazon region to the rest of the country (with the successive PINs). In Mato Grosso, a good part of the funds made available by the federal government through a variety of programs and institutions were captured by settlement projects led by private companies approved by the state but was disproportionately captured by ranching projects in areas of forest, the priority of the military regime. Although these colonizadoras mostly focused on cattle-ranching throughout the state, a slim portion of them aimed at developing agriculture (e.g. rice cultivation) by bringing smallholders from the southern states of Brazil searching for larger areas to cultivate.

These agriculture-oriented colonization projects primarily took place in the Amazon-Cerrado transition areas of Mato Grosso, centered around the BR-163 region. The reason they were organized around agriculture is not entirely clear but it likely had to do with the vision of *colonizadora* founders who themselves were farmers and entrepreneurs in the southern Brazil. These *colonizadoras* brought numerous smallholders from the South, offering the creation of a city, schools, hospitals, and the necessary infrastructures to support the rough conditions of initial settlement in Mato Grosso. Nonetheless, I showed that the story did not unfold the same way in the Chapada dos Parecis area in which they were fewer *colonizadoras*, or simply individuals distributing land to colonizers without lending the same services than in the BR-163. The fact that farmers in the Parecis area, in absence of *colonizadoras*, were able to develop agriculture in similar

ways to the BR-163 show that the agricultural vision that may be attributed to *colonizadora* founders was in fact widely shared by this group of highly motivated colonizers.

These colonization projects found themselves however at the center of a unique combination of factors (technological advances in soybean cultivation, favorable climate conditions and infrastructures, federal support with agricultural programs and financing, and strong world demand for soybean) that enabled a very specific group of smallholder farmers from southern Brazil to succeed in the area. One of the key features of this colonization story was the development of agricultural technology and practices adapted to Cerrado soils. Brazilian research institutions (through significant scientific cooperation with American research organizations), developed a way to reduce Cerrado's soil acidity by adding lime. Another breakthrough was the creation of soybean variety adapted to the shorter photoperiods of low tropical latitudes. Other innovations included planting calendars to the Cerrado, no till systems, nitrogen biological fixation, and many others.

Chapter 1 concluded that these conditions alone did not explain how such a group of producers were able to turn these areas into the leader in soybean production. The objective of Chapter 2 was therefore to answer to how this group was able to achieve this. Nonetheless the elements outlined in Chapter 1 help filling in the boxes Resource system and Resource units on the left-hand side of **Figure 7.1**. In sum, in the late 1970s, when the first pioneers arrived in the BR-163 highway area, the road had just been constructed to integrate forested areas of northern Mato Grosso with the remainder of the country. Few colonizers had prioritized the Amazon-Cerrado transition areas since colonizers from the South and the government are focused on the forest. A small group of

colonizers, however, either followed the lead of a few colonizadoras determined to start agricultural activities in the BR-163, or carried their own agricultural vision in the Chapada dos Parecis, for which a road (the MT-070 will only be built in the 1980s). Many of these colonizers failed at the time because of the low success of rice cultivation in the area, quickly exhausting soils. Chapter 1 also indicated some changes that will contribute to improve the agricultural activity in this frontier. The situation started improving as producers experiment with soybean varieties adapted to low latitudes and developed by public research (right-hand side of the box). The construction of the BR-163 highway, in the 1970s, and that of the MT-070, in the 1980s, significantly contributed to improving market access although distance still remained a challenge.

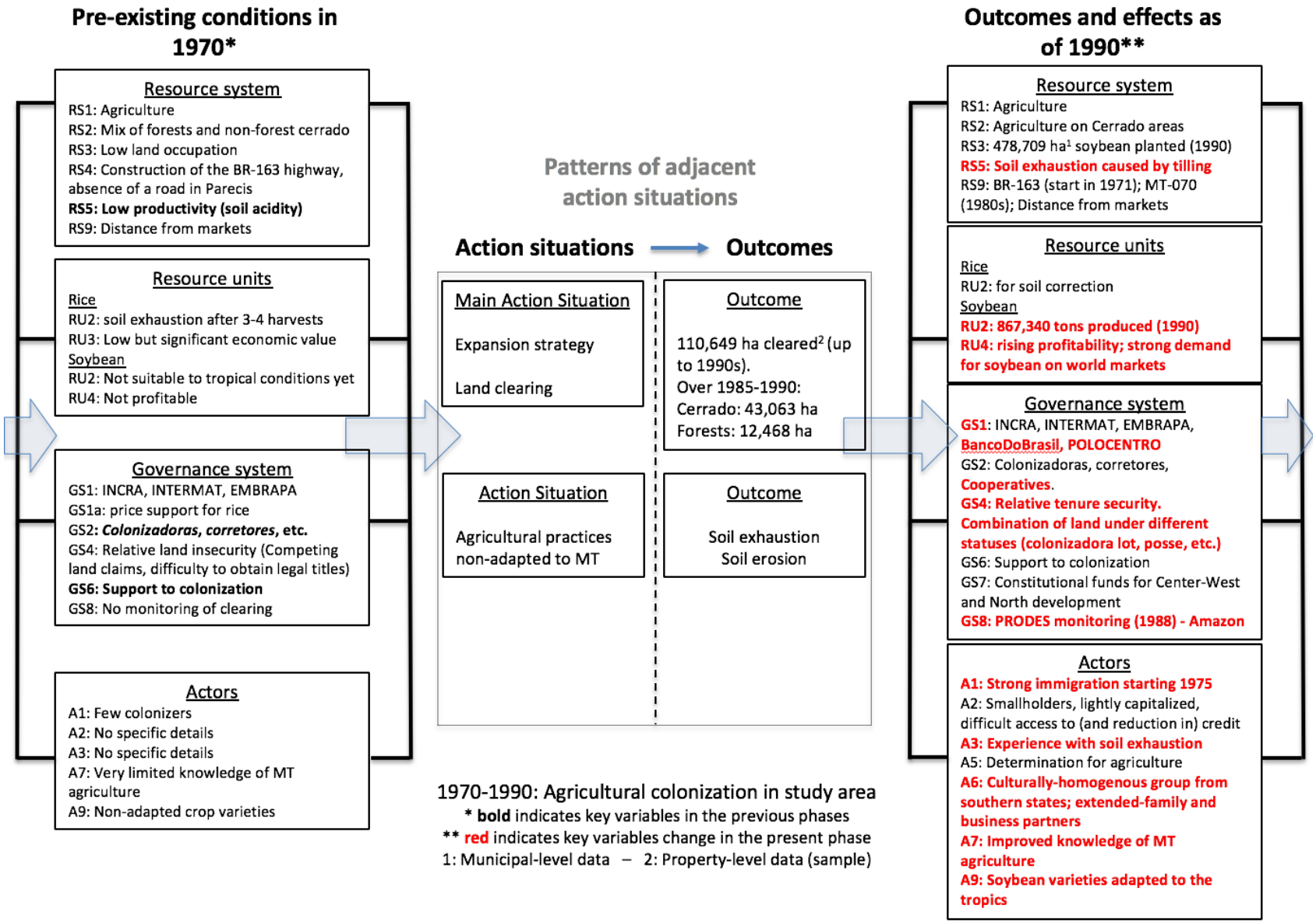


Figure 7.1. CIS framework representation of the transition of large-scale soybean producers from the early stages of the colonization (starting in the late 1970s) to right before the great acceleration of soybean production in the 1990s

1.2. THE POWERFUL AND SHARED VISION FOR AGRICULTURE OF THE COLONIZERS OF AMAZON-CERRADO TRANSITION AREAS (CHAPTER 2)

Although the structural and institutional conditions were favorable to the colonization of Mato Grosso, the "human" factor was key. Thus, the evolution of smallholder colonizers into large-scale soybean producers was the result of a unique "techno-cultural identity" of colonizers, which finds its roots in the interaction between individual and group characteristics of southern farmers with a particular technological package (innovations in semi-arid and tropical agriculture) and state support. This chapter helps filling the remainder of the boxes on the left-hand side of **Figure 7.1** (Governance system, Actors), and also on the right-hand side since it contains much information about how production and producers evolved throughout the study period (Resource system, Resource units, Governance system, Actors).

Simply put, this group of farmers came to the area to farm. The individuals and families who arrived in Mato Grosso presented diverse types of life trajectories, although a large majority of producers came from smallholder families, and all of them came from the southern states of Brazil (Rio Grande do Sul, Santa Catarina, Paraná) (at the exception of 18 individuals over 104, most of whom were children of pioneers born in Mato Grosso). Producers are from European-descent and their families owned no more than 24 or 48 hectares in southern Brazil. Thus, they had to join forces with family members (brothers, cousins, father and sons, …) or others (friends, business partners) to colonize Mato Grosso (**Figure 7.1.** Actors box, right-hand side). Rather than arriving in distinct "waves," the data reveals a continuous flow of migrants across the 1978 to 1989 period, with a smaller new wave of colonizers in the mid-1990s (the bulk of migrants arrived around 1984). Migration paths were diverse, and colonizers arrived by doing "little jumps" from one state

to the other along the Center-West frontier or leaped frog to Mato Grosso directly. The decision of migrating took, for most colonizers, considerable (mostly time-wise) investments (i.e. actively looking for land) in traveling, when the trips were not paid for by colonizadoras trying to attract migrants to the region.

I relied on 5 stories of large-scale soybean producers to illustrate the diversity of trajectories, going against the idea that the colonization trajectories of these farmers would be somewhat very similar. The idea of an "average" profile of colonizers creates a myth around it (i.e. the small/medium farmer from the south becoming a wealthy producer), and conveys the idea that this group was privileged by public policies and that they owe their success *only to public policies*. In fact, although this group of farmers was indeed indubitably prioritized by public policies, this picture hides the high failure rates experienced by colonizers and much of the rough colonization start and difficulty in successfully running profitable agricultural activities.

I thus outlined a new model of life trajectory for this group of farmers, generalizing from the data but remaining sensitive to the individual differences within the sample. It turned out that large-scale producers had overall a more diverse set of trajectories than previously evidenced by the literature (with conclusions based on smaller samples or simply "anecdotal" evidence). This led to a 'reformulation', in a sense, of the way land accumulation at the frontier can be represented. Producers have chosen to acquire different types of land (official land lots, *posse*, second-hand titles) (**Figure 7.1.** Governance system box, right-hand side). In that respect, producers seem to have combined very diverse types of titles and levels of tenure security, some not hesitating to sell an official title guaranteed by a colonization firm in exchange of greater areas under no legal title.

Many *colonizadoras* indeed have insecure titles (although they were pretending to sell the opposite) and it was often far easier to get title recognition from INTERMAT or INCRA on *posse*, as demonstrated in a large extent by colonizers of the Chapada dos Parecis who almost all settled that way. This challenges the dominant narrative according to which they got their land either from private colonizadoras or public colonization schemes.

Examining the tenure regularization profile in each municipality of the study, I nuanced two ideas about the frontier: (1) land tenure security did not depend on the category of land title since in one place *colonizadora* titles could be secure but not in others; (2) the Parecis region did not use *colonizadoras* per se but achieved similar progress than the BR-163 (**Figure 7.1.** Governance system box, right-hand side). The fact that landowners combined different types of property, including risky ones where tenure security was not necessarily well-established helps us question the rationale according to which colonizers would "prefer" secure titles over non-secure ones. In some cases, no land tenure security is necessarily achieved by a formal/legal title, while landowners successfully got tenure security on land with no title. Furthermore, risk could be diversified by combining different types of land ownership. In sum, this part nuanced the interpretation according to which tenure security in the frontier depended on clearly defined titles. It also contrasts with the interpretation according to which colonizadora and cooperatives have been the key actors of private colonization by minimizing the transaction costs associated with colonization (defining land titles, creating market connections, etc.). In fact, tenure security much depended on the local context rather than specific organizations in charge of the colonization.

After a decade or so running agricultural activities, when families and business partners had not failed, many had to split their large property into smaller ones because of growing families and the need to invite children into the activity. This led some interviewees to anecdotally say that this was the only type of "real" land reform. Today, many producers to further split their property due to the inheritance of their children, some deciding to take up the activity and others deciding to sell their share of inheritance to pursue another life. What this part therefore spoke most to are frontier theories. It showed that (1) an agent decision to migrate rested on a wider social network than thought (with help of private colonization firms) that is culturally homogenous and (2) most farmers came from the 1980s showing a different picture that that of a "turnover" cycle shown by frontier theory where newer capitalized farmers buy up the land of failing or weak farmers who cleared land for them.

Farmers settled in the frontier by first cultivating rice and only started soybean around 1982 (in the study area) (**Figure 7.1.** Resource units box, right-hand side). Their agricultural practices evolved in different stages following the cultivation and economic challenges faced by their production systems. For most producers, the land consolidation and accumulation processes were sporadic, as many of them did not make additional purchases until 15-20 years after the acquisition of their first land lot in the area. The initial clearing of land happened over a period when the economic situation in Brazil led to reductions in participation of the state in agricultural funding (1985-1990). Given the high inflation rates, producers privileged investing the harvest earnings into land than other types of investments. The consolidation patterns were diverse, some preferring to buy close to their original properties while others were more "expansionist" trading land

frantically looking to improve their market positioning (close to infrastructures) as much as they could.

Chapter 2 provided also a snapshot of who large-scale soybean producers are today and what space they occupy in the post-frontier soybean producing areas of Mato Grosso (**Figure 7.2**. **and 7.3**., Actors boxes). About half of the interviewed producers have a high school diploma or a higher education degree, meaning that the other half had no other choice than (or chose to) leaving school to farm. Within the group of large-scale landowners there is a large distribution of property sizes ranging from 2,000 ha to 20,000 ha and above. They tend to own or rent land both within and outside the municipality where they reside while renting land has been one of the privileged way to expand cultivated given that today land prices are very high. Their production system is dominantly double-cropping soybean-maize or soybean-cotton (a minority of highly capitalized farmers) and one can witness the increasing use of cover crops during the inter-season. Producers are increasingly moving toward self-funding to get away from the dependency from input resellers or banks, getting more independence. In the past, a greater part of their funding came from banks, cooperatives, or input resellers (including multinationals). These producers are very well-informed and access a variety of media about farming techniques, many are advised by consulting firms. In short, large-scale producers represent a partly educated, partly non-educated, group that control large extents of land on which they practice seemingly similar production systems. They are well-informed and increasingly try to become financially independent (they have access to a wide variety of funding anyways). This last point has implications for the type of environmental policies to be applied (e.g. policies that sanction based on credit).

Chapter 2 makes a clear case that the producers arriving in Mato Grosso were gambling when they decided to settle in the Amazon-Cerrado transition areas. The pioneers arriving in the 1970s had to prove the agricultural potential of the area and many of them failed. Those arriving in the 1980s, the bulk of which constitutes the group of large-scale soybean producers arrived in an area where soybean production was only appearing, and still faced considerable economic difficulties. Hence, despite some state support (which often required some advocacy from producers), the colonization story reveals the strong determination of a group of people to transform a region into the agricultural potential it has today. Other regions received state support but did not transform it into similar economic success.

1.3. THE REINFORCEMENT BUT UNEVEN ENFORCEMENT OF ENVIRONMENTAL POLICIES (CHAPTER 3)

The colonization and subsequent rapid expansion of soybean in the Amazon-Cerrado transition areas of Mato Grosso in the 1990s and early 2000s led to extensive deforestation. The objective of Chapter 3 it to assess the extent to which the heightened enforcement of environmental policies around the 2000s has affected the Amazon-Cerrado transition areas. The fact that production increased without causing much further deforestation after 2005 has been fueling the debate about whether this area was an 'exemplary' case of land sparing through production intensification and efficient environmental policies. This chapter helps filling in the Governance system boxes of **figures 7.1, 7.2, and 7.3**.

In this chapter, I argued that the Amazon-Cerrado transition area did not receive as much policy pressure as other areas (like the Amazon biome), it therefore makes it an interesting case for exploring the effects that other factors have played. Despite being aware that deforestation would

not go unsanctioned since the *Nossa Natureza* program in 1988, landowners in the Legal Amazon did not see threats materializing until the mid-2000s (**Figure 7.1.,** Governance systems boxes). The anti-deforestation efforts of the federal government focused on the Amazon biome and did not have much teeth until 2004, when deforestation monitoring data became more frequently available (DETER system) and when the enforcement capacities of environmental agencies were strengthened (PPCDAm). Even then, most enforcement operations occurred in the Amazon biome whereas the Cerrado biome only started to be subject to some anti-deforestation plans only after 2009.

I reviewed additional factors that may have contributed non-compliance by producers. The evolution of federal-and state-level environmental policies and their articulation with one another revealed major inconsistencies, which probably created a feeling of instability in the rules (especially as it relates to the status under the Forest Code of transition vegetation areas). Part of the inconsistencies came from the decentralization of environmental policy at the state-level in the 1990s. Mato Grosso was a pioneer in that effort, getting its own Environmental Code in 1995 and signing a pact with the federal government in 1999 to have its own state environmental agency (SEMA, then FEMA) enforce environmental policies. However, divergences in the interpretation of LR percentages for transition areas demonstrated the difficulty of articulating environmental policy between the federal and state levels.

The multiple revisions of parts or all of the Forest Code (first elaborated in 1934, revised in 1965, 1989, 1996, 2001, 2012) led the LR percentage for rural properties located in the Amazon-Cerrado transition areas to go up and down several times. Furthermore, Mato Grosso's rural

properties in forest-cerrado transition area were confronted to some uncertainty about which LR percentage to apply. Although this uncertainty may have well suited the interests of some producers wanting to clear as much area as possible, it rewarded the cunningness of these producers while puzzling those willing to comply, in addition the significant frustration created by knowing that some disregarded the rules (**Figure 7.2.,** Governance systems box, right-hand side).

The examination of deforestation rates in the state of Mato Grosso demonstrated that most deforestation in the Amazon-Cerrado transition areas occurred until 2005 or so. The direct conversion of native vegetation peaked in the period right before, following a combination of favorable economic conditions (e.g. soybean price, exchange rates, rural credit availability, and low policy enforcement). Nonetheless, there was a decrease in deforestation at the state-level and also locally in Amazon-Cerrado transition areas after 2005. The fact that this may have been caused by variation in market conditions (e.g. crisis of 2004 and 2005) or market-based initiatives (e.g. Soybean Moratorium, etc.), adds to the uncertainty about what caused deforestation to drop. Additionally, indirect land-use change has appeared as a potential cause of further expansion over forests (but not of soybeans) in other areas of Mato Grosso.

The impact of environmental policies on deforestation rates in the Amazon-Cerrado transition areas is fairly unclear since: (1) By design, environmental policies meant to stop deforestation have concerned mostly areas of the Amazon, putting relatively less pressure on Amazon-Cerrado transition areas; (2) Due to the multiplication of public policies and zero-deforestation initiatives, it is unclear to which policies one can attribute the decrease of Mato Grosso's deforestation, especially in these areas; (3) Most studies on the effectiveness of environmental policies based

their analysis on PRODES data, which mostly covered the Amazon biome and not the Cerrado biome (**Figure 7.2.,** Governance systems box, right-hand side). I concluded that the uncertainty about what made deforestation rates drop after 2005 in the study area called for a careful property-level examination of land clearing, which was the focus of Chapter 4.

1.4. A COMMON AND UNSTOPPABLE PLAN FOR SOYBEAN PRODUCTION UNTIL 2005 (CHAPTER 4)

Chapter 4 provided several insights into the clearing patterns of large-scale soybean producers over 30 years (1985-2015). The research questions were: (1) Do we observe changes in the rate and pace of land clearings over the period of analysis? (2) Can these changes be related to institutional (policy) changes or do they have more to do with economic conditions? The basis of the reasoning for hypotheses was the following: since each individual has different characteristics, we were expecting to see differences in clearing rates between producers (H1). What is more, farmers in the study are situated in different landscape and economic conditions and colonization trajectories depending on the municipality and biome, so we were expecting to see a common pattern across properties located in the Cerrado areas (H2). Finally, as Cerrado areas received less policy pressure, we were expecting to see less of a response to policies on the part of these properties (H3). The insights from this chapter helps filling in the Action situations and Outcomes boxes of **figures 7.1, 7.2, and 7.3.**

The results of the land-use change analysis confirmed commonalities and differences in the property-level clearing patters of soybean producers. Producers shared a common for agriculture and cleared native vegetation at a steady pace to make room for crops. They tended to clear non-forest cerrado vegetation first and then started clearing forests. Interestingly, all clearing stopped

on properties after 2005. Proof of a "common plan" (not an agreed upon one, of course), there were no major differences in the clearing threshold of properties located either in the Cerrado or Amazon biomes.

However, one can note several qualitative (i.e. type of clearing), quantitative (i.e. extent of clearing), and temporal differences (i.e. timing of clearing). Starting with differences between the two areas of study, I observed that clearing in rural properties of the Chapada Parecis was swift (in less than 20 years) as the vegetation cleared there was mostly non-forest cerrado types. On the contrary, properties of the BR-163 originally presented a different mix of vegetation cover, with a higher ratio of forests as compared to non-forest cerrado areas, and a longer colonization history. At the same time properties of the Chapada dos Parecis were clearing non-forest cerrado areas, similar vegetation cover on the BR-163 area properties had been extensively cleared and most properties were starting to clear forests. In particular, differences in municipal-level trends showed that fewer forests were cleared in the Chapada dos Parecis than in the BR-163, partly because properties there included more non-forest Cerrado vegetation than properties in the BR-163 (which faced a 50% Cerrado – 50% forest vegetation profile overall).

The fact that properties located in both biomes did not present, on average, major differences in clearing extent has been a surprising result which can partly be explained by the common plan shared by producers. It however means that rural properties located in the Amazon biome (an area predominantly occupied by forests) generally disrespected old and new clearing limits established by the Forest Code (FC) modifications of 1996 and 2001. Properties in the Cerrado disrespected the new limits of 2001 but seem to have respected the old ones. Most importantly, landowners in

both biomes kept clearing despite LR percentage changes, pointing to the strength of market factors behind soybean expansion in the early 2000s. One important difference however: Contrary to most rural properties in the Amazon biome which had already crossed their legally authorized clearing limits for forest areas when the law changed, some properties located in the Cerrado biome crossed the limit after the change was enacted.

The effect of policies to reduce deforestation is difficult to disentangle. What the analysis revealed is that all producers seem to have shared a common plan because they all cleared relatively high shares of their property, regardless of the biome or municipality. However, the date at which they plateaued (i.e. maximum cleared area) is different. The size and timing of the different plateaus seemed to be time and size invariant, although smallest properties seemed to reach their plateau more quickly. This made the interpretation of the data difficult since it is harder to attribute potential causes to the halt of clearing. For instance, several producers stopped clearing as early as 1995, or quite small areas between 1995 and 2005. It is difficult to interpret what factors led some landowners to stop clearing at this stage because their plateau differ from each other.

It appears fairly clear, however, that the majority of producers did not take heed of the LR changes occurring in 1996 for forest-dominated areas and 2001 for Cerrado-dominated areas. It is unclear whether the general stalling of clearing rates in 2005 is a result of the agricultural crisis of 2004-2005 or the creation of the PPCDAm. However, two things appear in the analysis. First, in 2005, many properties had reached the LR limit or were well past it. Second, many properties had already stopped clearing before the 2000s, and present different shares of cleared area which demonstrates that producers do not necessarily stop right at the LR limit. These producers may

have reached other biophysical or financial limits that forced them to switch from extensive to intensive production systems. However, given the variability of plateaus reached by properties, a hypothesis based on biophysical limits is at best incomplete.

On the contrary, the fact that properties with both small and large extent of cleared land stop expanding at the same time supports the idea of changing financial conditions and production systems. The major limit of this chapter is to not analyze the compliance of rural properties with the FC based on the transition vegetation areas where the LR limit would be 80% (50% before 2005). The reason for not proceeding to such analysis is because the RADAM vegetation classification has a coarse resolution that would result in a gross misclassification of properties in the sample into three potential categories: forest-dominated, transition-dominated, and Cerrado-dominated areas. It is possible that the properties that cleared less of their area in percentage were those located in areas of forest transition. However, it is fairly unlikely because all the properties in forest areas of Sinop did not respect the LR percentage that applied to them. In fact, one can only be surprised to see such extent of land clearing across the whole sample knowing that in many transition areas, rural properties ought to have respected higher LR limits than the one applying to Cerrado-dominated areas (20% of the property area before 2001, 35% after), especially in the BR-163 region. It thus seems fair to speculate that an overwhelming majority of properties disrespected the limits established by the Forest Code. This may be due to a general misunderstanding of the rules (particularly blurry and instable in the case of transition areas) (Stickler et al. 2013) or this may be explained by the fact that producers did not take them into consideration when deciding what the optimal area to be cultivated should be.

The analysis of the relationship between property size and land clearing rates reveals that, overall, smaller properties tended to clear a larger share of their area than larger properties. However, this observation needs to be clearly nuanced. First, the group of large properties present the same extreme (low and high) clearing extents than groups of medium and small properties. Most interestingly, the size of property tended to be correlated with the time at which producers ceased to clear land (plateau). Smaller properties tend to hit plateaus earlier than larger properties, while properties over 10,000 ha almost unanimously accelerated land clearing in the period where they were not allowed to (between 2000 and 2005). Second, the small properties included in the sample tended to only represent 45-55% of the total landholdings of a given farmer in this category (i.e. farmers with small properties in the sample tended to own additional properties). It would therefore be incorrect to say that small farmers clear more land than larger farmers. Regardless of these observations, the most striking finding is the relative similarity, rather than the difference, of clearing plateaus (around 70-80% of total area cleared) across all property sizes in the sample, regardless of biomes.

Some of the land-use change results are reflected in producers' perceptions of public policies to reduce deforestation it seems. Producers in municipalities that were the last to deforest extensively seemed to attribute a good part of the behavioral change to fines by SEMA and IBAMA. Sinop was the outlier in all categories of policies which partly confirms the greater influence of policies there, in the Amazon biome. Interestingly, the Soybean Moratorium appeared to be more of an annoyance in the municipalities that were last to deforest (i.e. Sinop and Campos de Júlio).

As a result, H1 was confirmed as producers presented a wide variety of clearing plateaus (or limits). However, H2 was not fully confirmed since there are some differences in the way land clearing unfolded between the BR-163 and Chapada dos Parecis region. However, I found relatively similar clearing plateaus across municipalities and biomes (timing-wise Sinop is the last to clear native vegetation. Finally, H3 was not verified since properties in all municipalities and biomes all stopped clearing in 2005. It either meant that the "hypothetical" lesser policy pressure effect in the Cerrado was not at play or that it also included Sinop. However, this abrupt stop may have also been trumped by the importance other factors played in causing land clearing to stop (market conditions, etc.).

This chapter helped answer some important questions related to producer's behavior when it comes to deforestation. Were soybean producers careful planners or opportunistic agents taking advantage of market fluctuations? The property-level analysis reveals that it is not clear at all whether land clearing rates followed market conditions opportunistically, because rates decreased or increased in different municipalities or for different property sizes at time periods where economic conditions were the same for all of them. It is not clear either whether producers took heed of environmental policies. If most producers kept at least a 20% to 30% LR on their property, the fact that the amount of native vegetation protected does not follow a pattern linked to biomes (areas relatively more forested as opposed to areas where Cerrado vegetation predominates) is unsettling. This chapter has therefore painted a picture of soybean producers as a class that, despite differences, broadly shares the same economic plans in terms of the extent of land-use within their properties. If Chapter 4 shows that it is difficult to disentangle the influence of different market or

institutional factors on land clearing patterns, it does not address the question of how or why land clearing stopped, a topic I explore in Chapter 5.

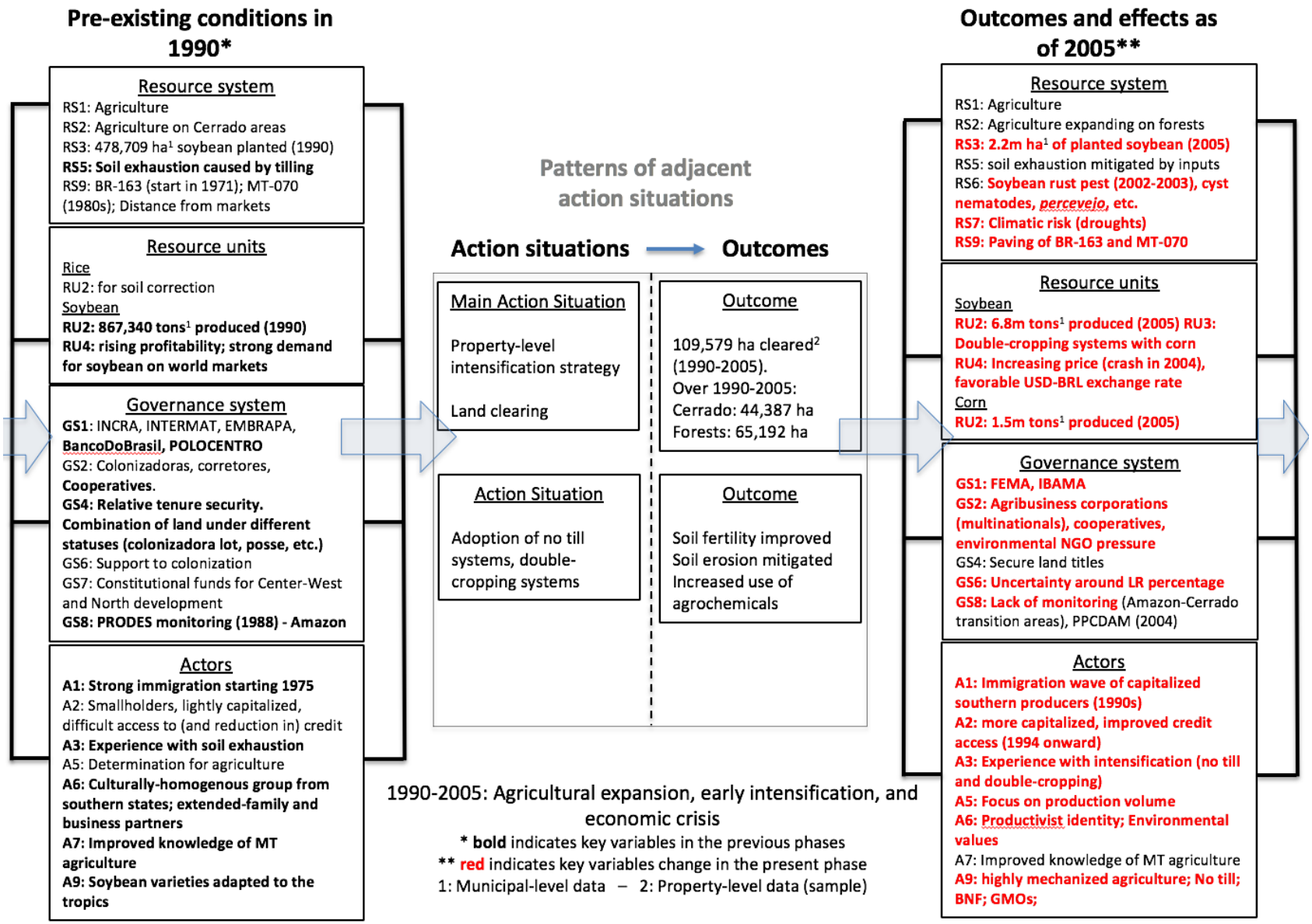


Figure 7.2. CIS framework representation of the expansion of soybean production under the impulse of global markets to the soybean crisis of 2004-2005 and heightened environmental policy enforcement of 2004.

1.5. EVOLVING PRODUCTION STRATEGIES AS ADAPTATION TO MARKET CONDITIONS, ENVIRONMENTAL POLICIES, AND CHANGING BUSINESS STRATEGIES (CHAPTER 5)

In chapter 5, we (I and co-authors) reviewed the process through which soybean producers transitioned from high- to low- deforestation. There is much debate about whether agricultural intensification leads to land sparing or not. In a way, by producing more output with the same area of land, intensification makes possible to produce the same amount of crops with less area. This assumption however rests upon the idea that, excluding other influences, the price of crop will remain the same or drop as more production is added. However, in many instances crop prices stay the same or increase, which actually turns the per hectare profitability of agricultural operations more up and thus encourage further expansion (in absence of countervailing forces). There is evidence that the early-stage intensification of soybean production in Mato Grosso did not slow down deforestation (specifically the 2000-2004 period). After 2005, production kept increasing despite declining deforestation rates and increased planted area, suggesting that soybeans replaced former pastures rather than native vegetation.

Together with my co-authors, I argued however that the non-expansion of soybean over native vegetation was made possible by changes in the production strategies of producers. Over time, producers of Mato Grosso have adapted their production strategies to changing biophysical conditions such as limits in soil fertility as well as economic conditions. We categorized 5 strategies and associated agricultural practices that producers relied on over time, with the caveat that producers can use agricultural practices from one or more categories, and not many have adopted those of the 'most advanced' categories (**Figure 7.1, 7.2, 7.3**, Action Situation boxes).

Furthermore, each strategy tended to change financial and environmental risks, and new strategies usually emerged to address the financial or environmental risks of the previous ones.

When smallholders from southern Brazil arrived in Mato Grosso, they followed an Expansionist Strategy (1980-2000). At that time, land was cheap, they had low capital (i.e. limiting expansion) and limited knowledge of soil fertility. The dominant strategy was therefore to produce as much crop volume as possible and expand on as much land as possible, since the two were intrinsically related. For many this expansion occurred within the property but for others it translated into the purchase of additional areas. Producers quickly met with the limitations of their production model, especially soil fertility, much of which still based on agricultural techniques suited for temperate climates (**Figure 7.1**, Action Situation and Outcomes).

It is in that context that no till systems emerged and producers started improving soil fertility and production volume (**Figure 7.2**, Action Situation and Outcomes). This marked the shift toward Property-Level Intensification Strategy, which involved a greater care of soils to ensure sustainable production volumes. Besides soil aspects, no till systems (almost unexpectedly) reinforced intensification. To work, no till systems require the generation of a large quantity of straw to cover fields during the interseason. Since millet was insufficient for this, producers started to plant corn as a "little" second harvest (i.e. *safrinha*), thus creating the double-cropping systems still in use today. From *safrinha*, the productivity gains achieved with this second harvest became a fully-fledge "second" harvest (*segunda safra*), which producers could trade at an interesting price on domestic and international markets, reducing their financial vulnerability (**See Figure 7.3** and the total production of corn difference between 2005 and 2015). This reinforcement of farm

profitability surely explain partly why, in the presence of favorable economic conditions in the late-1990s early-2000s soybean expanded fast, especially on native vegetation. This strategy came with serious environmental impacts however, reinforcing the use of agrochemicals (e.g. glyphosate) due to the two or three harvests a year instead of one.

After suffering a major economic crisis in 2004-2005 and the reinforcement of environmental policies in 2004, producers started focusing on the gains to be made from improving the management of the property area already available for cultivation (**Figure 7.3**, Action Situation and Outcomes). The Plot-Level Intensification Strategy (2005 onwards) refers to their realization that expansion could be risky because of the loss of control over their production operations as they expanded. Producers started looking at their (large) properties as a collection of land plots with variable soil fertility and realized that some investments (in high fertility plots) would pay off more than others (in low fertility plots). The gains from improving management processes, monitoring pests more closely (e.g. integrated pest management), and so forth, were significant as well. This strategy was therefore helping them to increase production by improving what they have, making expansion less attractive, especially in a context where it was increasingly difficult to convert new areas of production because of environmental policies.

In addition, producers learned from the 2004-2005 economic crisis that selling the harvest at a good price is key for long-term economic success. We thus labelled Commercialization Strategy (2005 onwards) all the practices concerning the actions of the producers outside their rural property. Producers started to make more advantageous purchasing decisions for inputs by joining cooperatives or purchasing groups (reinforcing their price bargaining power with suppliers) and

started using future contracts to sell their production at a pre-set price. This set of strategies had the advantage of minimizing financial risks while remaining neutral on the environmental side, if not beneficial in case an increased profitability could justify planting less crops.

Finally, a few producers are currently starting to diversify their production systems, having realized that their medium- and long-term profitability depended on it. In the context of what we named Diversification Strategy (2005 onwards), these producers prefer to plant primarily on high fertility soils, leaving lower fertility soils unused. In their mind, it does not make much economic (if not environmental) sense to put large quantities of fertilizers and agrochemicals on trying to obtain any yield from low fertility areas (**Figure 7.3**, Action Situation and Outcomes). By planting cover crops on them instead, they ensure the restoration of soil fertility for harvests one or two years down the line, while saving on production costs for the given year as well as ensuring that less investments will need to be made the year they will choose to produce on those plots.

Large-scale soybean producers thus play along commodity market scenarios and political conditions, but they tend to increasingly invest their resources wisely. As their vision of production systems is changing, along with their environmental values, they tend to use land in somewhat more sustainable ways than in the past, although many producers have not taken that direction yet.

1.6. CHANGING PERCEPTIONS AND ENVIRONMENTAL VALUES, A KEY ASPECT OF PRIVATE CONSERVATION (CHAPTER 6)

In the last Chapter, the objective was to demonstrate how environmental perceptions, values, and good agricultural practices (GAPs) reveal the building blocks of the producers' identity, but also the great diversity of opinions and ideas about the environment (**See figures 7.2 and 7.3**, Actors boxes)

I first reviewed how producers perceived the positive and negative impacts of deforestation, an analysis that revealed to a great extent a self-defined 'productivist' identity (i.e. self-identity) with which producers evaluate their actions (**Figure 7.2.,** Actors box, right-hand side). Producers tend to boast about the positive contribution they make to society through soybean agriculture and minimize their negative impacts through an environmental rhetoric putting forth their caring for soil health. Yet they demonstrated a real concern for environmental impacts. A little above half the interviewees recognized at least one of the following three adverse impacts of deforestation: reduction of wildlife habitats, impact on rivers, changes in local or global climate. Around a third recognized at least two of them. This concern is reflected in the pro-environmental values of producers who attach importance to forests for their role in water preservation (water value), biodiversity preservation (biodiversity value), and climate regulation (climate value). Producers appeared to strongly embrace the importance of forest conservation requirements as they related to riparian forests areas (for the protection of water bodies) whereas a significant portion discussed the way the LR was conceived, suggesting that its organization or size should be modified (downsized, for instance).

I then explored whether differences in pro-environmental values among producers influenced the adoption of GAPs. Since the sample is composed of large-scale farmers, I assumed that socio-economic variable did not have a significant effect on adoption of practices (H1). On the contrary, I assumed that pro-environmental values would have an impact on adoption (H2). The results showed that for soil and chemical GAPs, only one socio-economic characteristic stood out as influencing adoption (i.e. the training variable). For conservation GAPs, pro-environmental values are relatively more closely associated to adoption, in particular climate and biodiversity values, although the latter seems to have a negative effect on adoption.

I concluded that those who developed over time a sensitivity for the climate regulation services provided by forests (climate value) have been keener on adopting GAPs and more specifically conservation practices (**Figure 7.3.,** Actors box, right-hand side). If there is some evidence in support of the idea that pro-environmental values play an important role in farmers decision-making, it is definitely for a minority of farmers. I thus developed a conceptual model (**Figure 6.6**) summarizing the interactions between perceptions, values, and GAPs to demonstrate that the current behavior and thinking of soybean producers is the result of a subtle balance between these factors. It also shows that producers have evolved over time, from the period where they were clearing land to the period where they are in a stabilized frontier and have production systems that are less in geographical conflict with forests.

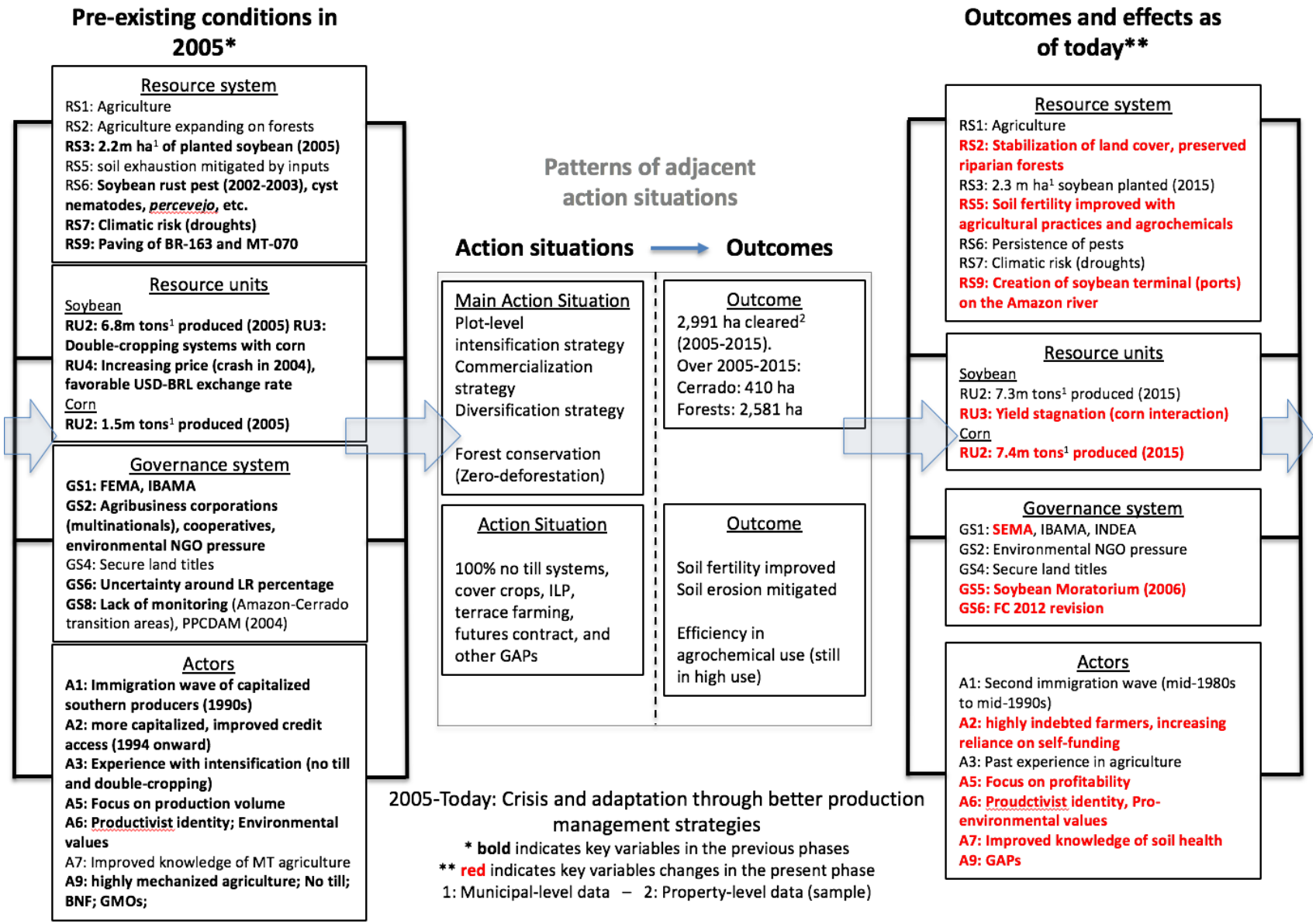


Figure 7.3. CIS framework representation of the large-scale soybean producers' strategies and land-use decisions from the mid-2005s to today, after the revision of the Forest Code (FC) in 2012.

2. LARGE-SCALE SOYBEAN PRODUCERS OF MATO GROSSO: WHO WILL PIONEER SUSTAINABILITY?

Putting together the 3 CIS framework representations of how large-scale soybean producers evolved productions systems in the Amazon-Cerrado transition areas of Mato Grosso helps summarizing the main dynamics and interactions that have occurred over time (See **Figure 7.4**). Combining this with the conceptual model of the evolution of environmental values and perceptions, I explain how the evolution of the environmental behavior of these producers hold valuable lessons for policy-making.

Current explanations of transition from high to low deforestation rates for soybean production areas of Mato Grosso revolve around land scarcity (i.e. reduced availability of fertile land suitable for production) (Spera et al. 2014), environmental policies and market-based zero-deforestation initiatives (Thaler 2017; Gibbs et al. 2015; Nepstad et al. 2014), and the presence of economic infrastructures (e.g. soybean storage units, biodiesel factories) that allow greater agricultural intensification (Garrett et al. 2018; Garrett, Lambin, and Naylor 2013). Garrett et al. (2018) assessed that agglomeration economies, in fact, have played a large role in the greater intensification (i.e. soybean and corn) of the BR-163 area or Chapada dos Parecis than other areas of Mato Grosso. They also found that the effect of environmental policies was higher in areas where land availability (i.e. forest cover) was low, and that the increased costs created by regulations (i.e. if someone deforests) are enough to deter deforestation when land is already expensive, but not enough when land is cheap (i.e. where forests are still abundant).

The objective of this dissertation was to demonstrate that there is more to the story than just costs and benefits (in which case behaviors would be highly homogenous). To be sure, when

smallholder colonizers from the South arrived in Mato Grosso, they acquired large areas and their agricultural knowledge was not adapted to local conditions. Several factors led them to clear land quickly: the easiness with which to clear non-forest Cerrado areas, the need to secure tenure, the drive to produce the maximum total crop volume, and the absence of environmental policy monitoring (i.e. which rather was an encouragement to clear land from the government). Despite the obstacles to land clearing created by the lack of capital, many joined forces and helped each other out to realize their crop cultivation plans, which were galvanized by the development of tropical soybean varieties by public agricultural research. This led to extensive clearing, but also to soil exhaustion since producers still relied on tilling and were not investing enough resources in to replenish the soils (**Figure 7.4**, left-hand side).

In the beginning of the 1990s, producers started noting the limits of their production models: with exhausted soils and productions costs rising, they needed to innovate. Part of the solution came from EMBRAPA through the development of numerous techniques to improve the profitability of soybean agriculture (no till systems, biological nitrogen-fixation, etc.) while the other came from the ingenuity of producers who started double-cropping systems consisting of soybean and corn to enhance the impacts of no till systems. These multiple innovations allowed agriculture not only to keep going in the area but also to thrive under ever-increasing soybean prices. Had such technological innovations been marginally important, producers would not be telling that no till systems were the "salvation" of the area (**Figure 7.4**., center).

The intensification of production systems set large-scale soybean producers on a prosperous economic path. It is no surprise that many of them significantly expanded their area starting in the

mid-1990s with the betterment of production conditions (after difficult first years). This also corresponded to a time at which the pioneers' children were entering the activity and it was thus necessary for them to expand operations to include them, especially after they divided the farms they had originally formed with family members or business partners when they arrived in the area. It is no more a surprise that deforestation peaked in the area in 2003-2004 following favorable economic indicators (soybean prices, and exchange rate) and increased farm profitability induced by double-cropping systems.

Not all producers dealt with deforestation the same way, however. At a time when soybean production exploded in Mato Grosso, the large variability in the extent of deforestation within property and time at which producers stopped clearing suffice to demonstrate that the behavior of producers did not depend only on economic factors (Chapter 4). Some producers early on (1990s) disapproved of the fact that some of their neighbors deforested riparian areas, shaming the bottomless greediness of others. The reasons large extents of riparian areas were preserved (especially in the Chapada dos Parecis area) has therefore partly to do with the fact producers attached greater importance to these forest areas than those located on flat lands (more likely further away from rivers and thus encompassed in the property's Legal Reserve -LR- not the Area of Permanent Protection - APP). Some pointed out that farmers preserved riparian areas because they tended to be sandier and less fertile soils. However true this explanation is, the dissertation demonstrated that producers nonetheless preserved either small or large amount of forests both within and across the two regions included in the study area, a variation potentially greater than that of soil quality alone. Furthermore, recent research has demonstrated that soybean expand even on low and medium land suitability areas (Garrett et al. 2018). Planting soybean on less fertile

soils can always be made more attractive when productions costs are lowered by the proximity to production infrastructures (storage units, transport, etc.), the improvement of agricultural technology, or the low price of land. Hence an explanation of forest preservation based on soil quality is very incomplete since preservation always depend on a number of factors, among which the need for expansion or the pro-environmental values held by producers.

The combined shock of the soybean economic crisis in 2004-2005 and the reinforcement of environmental policies (starting in 2004) nonetheless marked many producers. The fact that producers became highly indebted after a period of swift expansion of the planted area may have signaled that expanding fast had not been the best idea they had. Furthermore, they started feeling that the accumulation of environmental policy measures both by the government (e.g. PPCDAm) and the market (e.g. Soybean Moratorium) made further deforestation economically unattractive. Having been on the path of intensification, they perceived that it was possible to remain profitable with the same area (or even less), especially as they increased the volume of corn they produced every year as part of the second harvest. In addition, the multiplication of pests required better monitoring of crop land and investments in soil quality, which in turn required an ever-increasing quantity of agrochemicals to be put in the land (**Figure 7.4**, center). If we add up the increasing land price, increasing production costs, and increase costs of illegal deforestation, it is hard to remain profitable unless one improves profitability through greater production efficiency. This situation differs greatly from the times at which pioneers could 'plant and go to the beach' in the 1980s, and required producers to become real entrepreneurs managing a large number of production variables (Carauta et al. 2016), including non-production ones such as crop commercialization on commodity markets (Chapter 5).

The zero-deforestation state in which all rural properties in the sample found themselves after 2005, regardless of their location or cleared extent, demonstrates that environmental policies have played an important role (Figure 7.4, center and right-hand side). If they had not, we would have expected producers with a significant remaining vegetation to clear after 2005 given the renewed economic conditions. It is yet still difficult to characterize this policy effect. Anti-deforestation policies were enacted at a time of great deforestation, but the government was mostly alarmed by the expansion of cattle-ranching into the Amazon biome (and to a minor extent, that of soybean cultivation). Thus, in a way, it is the extensive land-clearing occurring in forest areas of the Legal Amazon (an adjacent action situation to the one of interest) that created momentum for policy regulation that applied also to soybean production areas in the Cerrado portion of the Legal Amazon (the action situation of interest). When asked about the influence of environmental policies, most producers declared that they had a limited influence, except those located in the Amazon biome that seemed to attribute a greater impact to them. It is possible therefore, that the effect of environmental policy has been more one of perception of potential enforcement rather than one of actual enforcement (Producers in Sinop have witnessed IBAMA operations to shut down illegal sawmills on 2005, which may be an example of perceived enforcement).

What the interviews showed however was that most producers thought that expansion does not makes sense anymore, given current economic conditions. To be sure, many of them owned properties elsewhere in the municipality or outside (some even held properties in other states that are new soybean frontiers, e.g. Bahia, Roraima) and may think about clearing in those areas one day if it makes economic sense or if, for example, they need to increase the planted area because

one of their children wants to join the activity. The focus of producers has now shifted on improving production by investing in soils, based on within-property differences in plot fertility. They try to reduce agrochemicals insofar as it reduces operational costs, but also driven by rising concerns about toxicity. A few have clearly expanded their production planning horizons to the medium- and long-term by doing crop rotation and leaving the less fertile soils on their property under cover crops for one or more years (i.e. taking land out of production). Although this is not a widely shared perception, a significant part of large-scale soybean producers are increasingly concerned by the changes that occurred in the local climate as a result of their expansion onto native vegetation (in addition of water-related and biodiversity-related concerns). Thus, the same way they realized the limits of their agricultural practices with soils in the past, some of them realize the limits of their agricultural model and seek for new strategies to produce sustainably. The right-hand side of Figure 7.4 shows the current state of soybean production areas, in between producers intensifying productions with the only perspective of profitability and new pioneers that look for the most sustainable way to minimize environmental impacts and ensure production over the long-term.

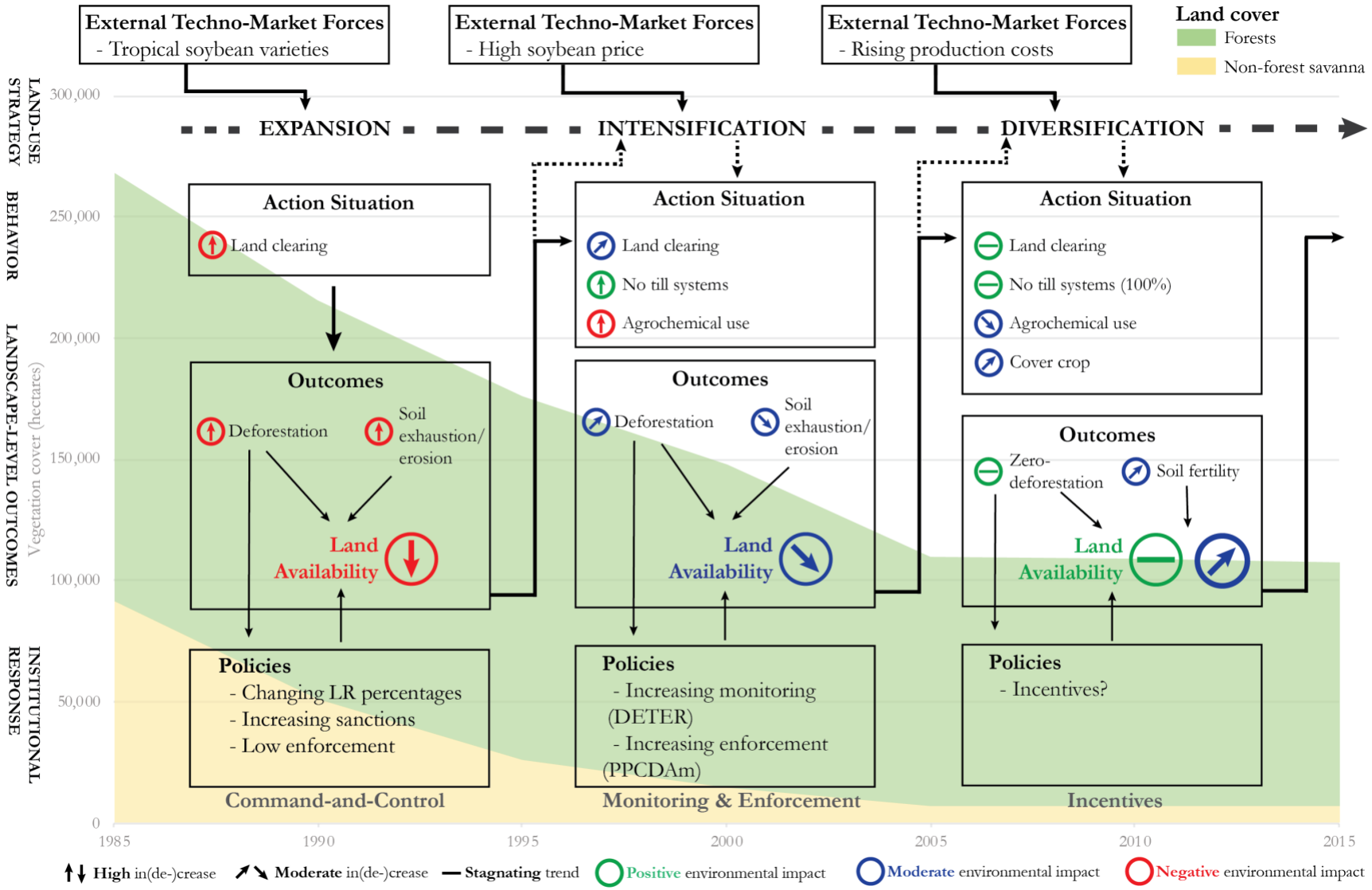


Figure 7.4. The evolution of large-scale soybean producers as the result of different action situations and contextual factors. The figure represents a condensed version of the CIS framework representations in figures 7.1, 7.2, and 7.3, outlining the dynamic relationships existing between each time period of colonization. Deforestation data is in hectares.

When I asked producers why they had stopped deforestation in after 2004-2005, they often replied to me that "there was nothing else to clear." It took me perhaps a while to understand it, but it actually did not mean that there were no more forests *per se* (since I have been in properties and municipalities with a significant amount of remaining forests), it actually meant that it was *not interesting to them anymore* to clear. If the research reveals one thing, it is that decisions about forest preservation are intrinsically related with those of crop cultivation, and that these two decisions are influenced by factors influencing each other. Many producers do not want to clear anymore simply because it would be more work, they are profitable "enough," and because they appreciate the presence of forests on their property. This also denotes the fact that they have developed pro-environmental values over time. Many remember the past mistakes of deforesting forests around springs and seeing water disappear. Others mention how their children would accuse them of destroying nature if they were to clear more land.

3. LESSONS FOR THE FUTURE: WHAT NEEDS TO BE DONE IN NEW COMMODITY FRONTIERS AND WHAT REMAINS TO BE KNOWN FROM OLD ONES?

An important aspect of this research, in my opinion, is that environmental policies may have worked well in the study area because producers could "afford" to comply with them, both economically and ideologically. The stagnation of land clearing in these areas is really the product of a subtle equilibrium of multiple contextual conditions and the decisions of a certain type of producers. As the increasing deforestation elsewhere demonstrated, environmental policies did not have a similar impact in every region of the Amazon and Cerrado biomes. The intense deforestation still occurring in the Amazon biome, or happening outside the Legal Amazon in the Cerrado areas of other states, is a timely reminder that environmental policies alone are not enough.

Large-scale soybean producers of the BR-163 highway area and the Chapada dos Parecis area have demonstrated that their production model and techno-cultural identity was compatible with zero-deforestation (at least in the study area), but it is unclear whether producers in other areas, provided they have similar technologies or identities, would have the same impact since contextual factors may disturb this subtle equilibrium.

Another important lesson is that getting "environmentally-responsible" producers may rely as much on strong environmental policies as innovative production systems made profitable through the improvement of production processes rather than the expansion of planted area. A largely unaddressed point in the Mato Grosso case, however, is the large consumption of agrochemicals by soybean agriculture, and even more so with double-cropping systems relying on crops or cotton (Bombardi 2017; Arvor et al. 2017). There were encouraging signs of producers relying on biological fertilizers or biological pesticides, however this was generally limited to less than 10% of the individuals interviewed. This is an important point to address at a time producers and their representative association (APROSOJA-MT) are working continuously to improve their image and increasingly use the marketing argument of "sustainable" soybean to sell on international markets.

The positive interaction between environmental policies and market conditions in Mato Grosso was the gradual transformation in production systems toward fewer financial and environmental risks (Chapter 5). Although soybean monoculture (or rather the "dual"-culture of soybean-corn or soybean-cotton) is not called into question in the farming community, many producers perceive the limitations of their production model. To some extent, they are dependent on what they have

always done, and what the economic system and multinationals around them allow them to do, which reveals the large path-dependency of these production systems. On the other hand, the recent observations of producers taking land out of production, conducting crop rotation, and multiplying cover crops or producing different crop varieties shed light on the small dents made to the dominant production pattern. These small modifications may well turn mainstream in the future since the producers adopting them did it to remain profitable.

Finally, future areas of commodity expansion will rely on human actors, even though some new areas seemed to be dominated by corporate structures, like new soybean areas in the Cerrado of MATOPIBA. Yet, whether within a corporation or as landowner-operators, the values carried by individuals in their productive activities will always be of chief importance to whether development minimizes environmental impacts. By showing that large-scale soybean producers developed environmental values over time at the same time they built an identity structured around productivism. This identity is the result of producers' interactions with nature, but also of their exposure to their neighbors' experiences, political debates, environmental NGOs concerns, and governmental agencies. Given the polarization of the environmental debate with the agribusiness sector in Brazil, I hope that describing these values and identity will lead others to perceive producers as human beings who have always been capable of change (let alone "re-humanizing" them for some). Of course, there is a long path ahead before all of the producers embody the values and identity described in this dissertation (which are by no means perfect). As reducing deforestation in Brazil is still the most cost-effective way to reduce GHG emissions (Gurgel and Paltsev 2014), one can only hope that this identity and those values be embraced by other producers as soon as possible. What should be the direction of agricultural development is beyond the scope

of my argument in this dissertation, I nonetheless hope that this work will be regarded as an invitation to discover and listen to each other's point of view, and create a more constructive dialogue between agricultural producers and society.

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Annex

1. CHAPTER 1

Note: Part of these methodological details are used for a paper currently submitted to Nature Ecology & Evolution, with co-authors Marion Daugeard and François-Michel Le Tourneau. This explains the use of "we" in the description below. Title of the paper: **The devil is in the details: How the wording of Brazil's Forest Code might open new doors for legal deforestation in the Amazon**

This methodological note's objective is to explain the methodology for classifying transition vegetation areas in Mato Grosso based on the RADAM mapping.

1. 1. DATA USED FOR THE VEGETATION CLASSIFICATION

1. **Datasets used for the land cover classification**:
   - Shapefile of Mato Grosso (downloaded on mapas.mma.gov.br in 2018)
   - Shapefile of RADAM vegetation (downloaded on mapas.mma.gov.br in 2017) – The dataset is not available anymore on the website of the Environment Ministry (MMA) and the authors can provide a copy of this dataset upon request.

2. **Clip of the RADAM shapefile using the Mato Grosso shapefile to get RADAM vegetation data only for Mato Grosso**.

For this step, we used the Clip tool from ArcMap 10.6.

- Input: RADAM shapefile
- Clip feature: Mato Grosso shapefile

1. 2. METHOD FOR CLASSIFYING VEGETATION

This section describes **how we reclassified the RADAM vegetation classes into new "vegetation" classes describing transition areas.** We followed to a large extent the classifications developed by Fearnside & Ferraz and used in the literature (Azevedo, 2009; Fearnside & Barbosa, 2003; Fearnside & Ferraz, 1995).

The attribute table of the RADAM dataset includes several columns. We worked with the following columns of data:

- NM_CONTACT and LEG_CONTAT: These columns indicate whether a given polygon of vegetation was classified as transition vegetation by the RADAM project. The column contains 8 different classes (including a blank class that we classified as "non-contact"). See table below for our reclassification of these areas)
- NM_UVEG: This column indicates the name of the vegetation type classified by the RADAM project. In the Legal Amazon area, there are 58 different types of vegetation classified by the RADAM (including a blank class that we classified as "other vegetation") in the Amazon biome and 33 in the Cerrado biome. See table below for our reclassification of these areas)

- LEGENDA: This column indicates the name of land-uses classified by the RADAM. It mostly overlaps with the NM_UVEG column but also classifies land-uses such as agriculture, ranching, urban areas, and so forth.

1. 2. 1. Classification of RADAM vegetation classes

For each biomes, we summarize the area of vegetation classes first by using the NM_UVEG column. This classification generates an important number of "blank" (or NA) values. In order to determine further the identify of these polygons, we used the column LEGENDA to further segregate polygons into land cover classes. Here is the detail and result of our reclassification.

Re-classified land cover	RADAM land cover class (Name in Portuguese)	RADAM column
Campinara	Campinara Arborizada ; Campinara Arbustiva ; Campinara Florestada ; Campinara com palmeiras ; Campinara sem palmeiras ; Campinarana Gramíneo-Lenhosa	NM_UVEG
Deciduous and Semi-Deciduous Seasonal Forests	Floresta Estacional Decidual das Terras Baixas com dossel emergente ; Floresta Estacional Decidual Submontana ; Floresta Estacional Decidual Submontana com dossel emergente ; Floresta Estacional Semidecidual Aluvial ; Floresta Estacional Semidecidual Aluvial com dossel emergente ; Floresta Estacional Semidecidual das Terras Baixas com dossel emergente ; Floresta Estacional Semidecidual Submontana ; Floresta Estacional Semidecidual Submontana com dossel emergente	NM_UVEG
Ombrophile Forests	Floresta Ombrófila Aberta Aluvial ; Floresta Ombrófila Aberta das Terras Baixas ; Floresta Ombrófila Aberta das Terras Baixas com cipós ; Floresta Ombrófila Aberta das Terras Baixas com palmeiras ; Floresta Ombrófila Aberta Submontana ; Floresta Ombrófila Aberta Submontana com bambus ; Floresta Ombrófila Aberta Submontana com cipós ; Floresta Ombrófila Aberta Submontana com palmeiras ; Floresta Ombrófila Aberta Submontana com sororocas ; Floresta Ombrófila Densa Aluvial ; Floresta Ombrófila Densa Aluvial com dossel emergente ; Floresta Ombrófila Densa das Terras Baixas ; Floresta Ombrófila Densa Montana ; Floresta Ombrófila Densa Submontana ; Floresta Ombrófila Densa Submontana com dossel emergente ; Floresta Ombrófila Densa Terras Baixas	NM_UVEG
Pioneer Zone Vegetation	Formação Pioneira com influência fluvial e/ou lacustre ; Formação Pioneira com influência fluvial e/ou lacustre arbustiva ; Formação Pioneira com influência fluvial e/ou lacustre arbustiva com palmeiras ; Formação Pioneira com influência fluvial e/ou lacustre arbustiva sem palmeiras ; Formação Pioneira com influência fluvial e/ou lacustre herbácea ; Formação Pioneira com influência fluvial e/ou lacustre herbácea sem palmeiras ; Formação Pioneira com influência fluvial e/ou lacustre palmeiral ; Formação Pioneira com influência fluviomarinha ; Formação Pioneira com influência fluviomarinha arbórea ; Formação Pioneira com influência marinha arbustiva	NM_UVEG
Savannas	Savana-Estépica Arborizada ; Savana-Estépica Florestada ; Savana-Estépica Parque ; Savana Arborizada ; Savana Arborizada com floresta-de-galeria ; Savana Arborizada sem floresta-de-galeria ; Savana Florestada ; Savana Gramíneo-Lenhosa ; Savana Gramíneo-Lenhosa com floresta-de-galeria ; Savana Gramíneo-Lenhosa sem floresta-de-galeria ; Savana Parque ; Savana Parque com floresta-de-galeria ; Savana Parque sem floresta-de-galeria	NM_UVEG

Mixed vegetation (other contact or indiscriminate)	Area indiscriminida ; LOt - Contato Campinarana/Floresta Ombrófila ; ONt - Contato Floresta Ombrófila/Floresta Estacional ; SNt - Contato Savana/Floresta Estacional ; SOt - Contato Savana/Floresta Ombrófila ; STt - Contato Savana/Savana-Estépica	LEGENDA
Other vegetation or land-uses (água)	Corpo d´água continental	LEGENDA
Anthropized area (agriculture, ranching, reforestation and secondary vegetation)	Acc.F - Culturas Cíclicas em Floresta Estacional Semidecidual ; Acc.S - Culturas Cíclicas em Savana ; Ag.A - Agropecuária em Floresta Ombrófila Aberta ; Ag.D - Agropecuária em Floresta Ombrófila Densa ; Ap.A - Pecuária (pastagens) em Floresta Ombrófila Aberta ; Ap.D - Pecuária (pastagens) em Floresta Ombrófila Densa ; Ap.F - Pecuária (pastagens) em Floresta Estacional Semidecidual ; Ap.LO - Pecuária (pastagens) em Contato Campinarana/Floresta Ombrófila ; Ap.ON - Pecuária (pastagens) em Contato Floresta Ombrófila/Floresta Estacional ; Ap.S - Pecuária (pastagens) em Savana ; Ap.SN - Pecuária (pastagens) em Contato Savana/Floresta Estacional ; Ap.SO - Pecuária (pastagens) em Contato Savana/Floresta Ombrófila ; Iu.D - Influência urbana em Floresta Ombrófila Densa ; Iu.F - Influência urbana em Floresta Estacional Semidecidual ; Iu.S - Influência urbana em Savana ; Iu.SO - Influência urbana em Contato Savana/Floresta Ombrófila ; R.D - Florestamento/Reflorestamento em Floresta Ombrófila Densa ; R.SO - Florestamento/Reflorestamento em Contato Savana/Floresta Ombrófila ; Vs.D - Vegetação Secundária em Floresta Ombrófila Densa ; Vs.SN - Vegetação Secundária em Contato Savana/Floresta Estacional ; Vsb.A - Vegetação Secundária só com palmeiras em Floresta Ombrófila Aberta ; Vsb.C - Vegetação Secundária só com palmeiras em Floresta Estacional Decidual ; Vsp.A - Vegetação Secundária com palmeiras em Floresta Ombrófila Aberta ; Vsp.C - Vegetação Secundária com palmeiras em Floresta Estacional Decidual ; Vsp.D - Vegetação Secundária com palmeiras em Floresta Ombrófila Densa ; Vss.A - Vegetação Secundária sem palmeiras em Floresta Ombrófila Aberta ; Vss.C - Vegetação Secundária sem palmeiras em Floresta Estacional Decidual ; Vss.D - Vegetação Secundária sem palmeiras em Floresta Ombrófila Densa ; Vss.F - Vegetação Secundária sem palmeiras em Floresta Estacional Semidecidual	LEGENDA

Table 1.a. RADAM mapping vegetation classes

1. 2. 2. Classification of transition areas

For classifying transition areas, we respected the RADAM classification by relying on the NM_CONTAT column. This column contained 5 different values for the Cerrado biome (including a blank class that we classified as "non-contact") and 8 different values for the Amazon biome (including a blank class that we classified as "non-contact").

Re-classified transition area	RADAM transition class (Name in Portuguese)	RADAM column
Transition Forest-Forest	"Contato Floresta Ombrofila/Floresta Estacional"	NM_CONTAT
Transition Savanna-Forest	"Contato Savana Estepica/Floresta Estacional" "Contato Savana/Floresta Estacional" "Contato Savana/Floresta Ombrofila"	NM_CONTAT
Transition Savanna-Savanna	"Contato Savana /Savana Estepica"	NM_CONTAT
Other transition	"Contato Campinarana/Floresta Ombrofila" "Contato Savana/Restinga"	NM_CONTAT
Non-transition	"Non Contat"	NM_CONTAT

Table 1.b. Re-classificaton of RADAM vegetation into transition vegetation classes

1° We first classified as **Transition Savanna-Forest** polygons based on the NM_Contat/LEG_CONTAT column and coded "Contato Savana/Floresta Estacional" (SN), "Contato Savana/Floresta Ombrofila" (SO), Contato Savana Estepica/Floresta Estacional (TN).

2° We then classified as **Transition Savanna-Savanna** polygons under the name "Contato Savana /Savana Estepica" (ST). Although indicated as "transition" areas by the RADAM, we considered these areas as savannas for our analysis, in accordance with Fearnside and Barboza 1995.

3° We then classified as **Transition Forest-Forest** polygons under the name "Contato Floresta Ombrofila/Floresta Estacional" (ON). Although indicated as "transition" areas by the RADAM, we considered these areas as forests for our analysis, contrary to Fearnside and Barboza 1995.

4° Polygons under the name ""Contato Campinarana/Floresta Ombrofila" and "Contato Savana/Restinga" were classified as **Other transition**.

Our classification is consistent with complementary law n°382 of January 12, 2010 of Mato Grosso state.

2. CHAPTER 5

Material corresponding to Annex and Supplementary Materials submitted jointly with the paper

2. 1. METHODOLOGY DETAILS

2. 1. 1. Municipality groupings: Selecting the top 40 soybean producers of Mato Grosso

To select the top 40 soybean producers of Mato Grosso in 2016, we relied on the production data made available by the IBGE at: https://sidra.ibge.gov.br/pesquisa/pam/tabelas

Municipality groupings: Applying an average score using three-tiered criteria

- *Selecting the municipalities with the highest area cleared by 2000*

We relied on the MapBiomas v3.0[303] dataset. We used the land cover dataset broken down by municipalities (File title: MapBiomas Col3 - COBERTURA_uf_biomas_municpios) and filtered by the coarser land-use classification (level 1).

1° We first calculated the area of each municipality based on this dataset to ensure consistency in the later area calculations
2° We then calculated the area of the municipality not covered by native vegetation at every year since 1985. To simplify, we used the Level 1 land-use class "nivel1" which correspond to the coarser degree of classification, which is also more accurate, and selected all the classes corresponding to non-vegetation or anthropized land-use: 3. Agropecuária, 4. Area Não Vegetada, 5. Corpo D'Aguá, 6. Não Observado.
3° We ranked municipalities following the highest share of municipality area cleared in 1995, which represents the oldest frontiers of Mato Grosso (be they soybean or cattle-ranching)

- *Selecting municipalities that deforested the least during the 1995-2017: further identifying old frontiers from the most recent ones*

1° Using the same data, we calculated the share of municipality area cleared between 1995-2007. For this, we simplified the calculation by simply taking the difference in area not covered by vegetation between the two dates.
2° We ranked the municipalities from 1 to 40 from the smallest area deforested to the largest area deforested. A small area deforested within that period suggests that the frontier was closer to being consolidated in 1995 whereas a high area deforested suggests that the municipality was most active

[303] "MapBiomas Project - is a multi-institutional initiative to generate annual land cover and use maps using automatic classification processes applied to satellite images. The complete description of the project can be found at http://mapbiomas.org" Project MapBiomas - Collection v.3.0 of Brazilian Land Cover & Use Map Series, accessed on November 15, 2018 through the link: http://mapbiomas.org/#

within the period. This gives a fair idea of which municipality was the most active in land clearing in the period after 1995.

- *Selecting municipalities that pioneered soybean production*

1° At this stage, the criteria have not enabled to distinguish frontiers driven by cattle-ranching from those driven by soybean production. We therefore calculated the soybean production level in the year 2000, a year that enables to avoid most problems of data availability linked to the creation of new administrative areas[304] and were the regions that pioneered soybean production in MT were still the original leaders (before some being recently overtaken by more recent frontiers).

2° We ranked the municipalities from 1 to 40 from the highest to lowest soybean production volume in 2000

- *Creating an average score to rank municipalities by historical/ original soybean production regions*

We combined the ranks associated with share of municipal area cleared in 1995, share of municipal area cleared between 1995 and 1997, and the soybean production volume in 2000 in one single table. Taking the average score obtained by each municipality across the rankings, we obtained a consolidated ranking in which the lowest values (close to 1) tend to be municipalities that were settled in the 1980s, either by cattle-ranching or agriculture, and were the first ones to take up soybean production in the state. The ranking values obtained ranged from 4 (e.g. Primavera do Leste) to 39 (e.g. Itanhangá). Based on our fieldwork experience and knowledge of the area, we decided to set up the cutoff value between the three group of municipalities to 20 and 27. As a result,

- Group 1 municipalities ($1 < X < 20$): 18 municipalities
- Group 2 municipalities ($20 < X < 27$): 12 municipalities
- Group 3 municipalities ($27 < X < 39$): 10 municipalities

Please see the following tables for the detail in rankings:

[304] Note that we did not use soybean production data to create subgroups of municipalities for the reason that this data is organized based on the year of creation of the municipality. Mato Grosso being still a state in formation at the time of the soybean boom, many municipalities were subdivided in multiple ones and the statistics may show a drop in production for one municipality that is actually caused because part of its production is accounted for in a newly created geographical unit. For instance, the municipality of Ipiranga do Norte was created in X and first accounted in production data in 2005 with a starting production volume of 463,188 tons.

MUNICIPALITY RANKINGS	**A.** Share Municipal Area Cleared in 1995	**B.** Share Municipal Area Cleared 1995-2017	**C.** Municipal Production Volume in 2000	**Average ranking score** (A+B+C)/3
Água Boa	7	11	24	14.0
Alto Garças	6	7	14	9.0
Bom Jesus do Araguaia	17	32	35	28.0
Brasnorte	28	28	17	24.3
Campo Novo do Parecis	13	9	2	8.0
Campo Verde	3	5	11	6.3
Campos de Júlio	24	25	10	19.7
Canarana	16	17	18	17.0
Cláudia	30	27	34	30.3
Comodoro	38	6	28	24.0
Diamantino	8	12	4	8.0
Feliz Natal	39	18	32	29.7
Gaúcha do Norte	35	20	25	26.7
Guiratinga	12	2	16	10.0
Ipiranga do Norte	27	39	36	34.0
Itanhangá	40	40	37	39.0
Itiquira	5	3	9	5.7
Lucas do Rio Verde	4	14	5	7.7
Nova Maringá	37	24	22	27.7
Nova Mutum	15	23	7	15.0
Nova Ubiratã	32	33	12	25.7
Novo São Joaquim	14	26	8	16.0
Paranatinga	22	16	27	21.7
Porto dos Gaúchos	33	35	30	32.7
Primavera do Leste	2	4	6	4.0
Querência	31	21	21	24.3
Rondonópolis	1	1	15	5.7
Santa Carmem	34	31	29	31.3
Santa Rita do Trivelato	18	22	38	26.0
Santo Antônio do Leste	10	15	39	21.3
São Félix do Araguaia	25	13	40	26.0
São José do Rio Claro	19	29	19	22.3
São José do Xingu	11	10	33	18.0
Sapezal	23	19	3	15.0
Sinop	20	37	23	26.7
Sorriso	9	30	1	13.3
Tabaporã	36	36	31	34.3
Tangará da Serra	26	8	20	18.0
Tapurah	21	34	13	22.7
Vera	29	38	26	31.0

Table 5.a. Municipality name, respecting ranking against three criteria and average score.

Municipality	Score	Group number	Municipality	Score	Group number
Primavera do Leste	4.0	Group 1	São José do Rio Claro	22.3	Group 2
Itiquira	5.7	Group 1	Tapurah	22.7	Group 2
Rondonópolis	5.7	Group 1	Comodoro	24.0	Group 2
Campo Verde	6.3	Group 1	Brasnorte	24.3	Group 2
Lucas do Rio Verde	7.7	Group 1	Querência	24.3	Group 2
Campo Novo do Parecis	8.0	Group 1	Nova Ubiratã	25.7	Group 2
Diamantino	8.0	Group 1	Santa Rita do Trivelato	26.0	Group 2
Alto Garças	9.0	Group 1	São Félix do Araguaia	26.0	Group 2
Guiratinga	10.0	Group 1	Gaúcha do Norte	26.7	Group 2
Sorriso	13.3	Group 1	Sinop	26.7	Group 2
Água Boa	14.0	Group 1	Nova Maringá	27.7	Group 3
Nova Mutum	15.0	Group 1	Bom Jesus do Araguaia	28.0	Group 3
Sapezal	15.0	Group 1	Feliz Natal	29.7	Group 3
Novo São Joaquim	16.0	Group 1	Cláudia	30.3	Group 3
Canarana	17.0	Group 1	Vera	31.0	Group 3
São José do Xingu	18.0	Group 1	Santa Carmem	31.3	Group 3
Tangará da Serra	18.0	Group 1	Porto dos Gaúchos	32.7	Group 3
Campos de Júlio	19.7	Group 1	Ipiranga do Norte	34.0	Group 3
Santo Antônio do Leste	21.3	Group 2	Tabaporã	34.3	Group 3
Paranatinga	21.7	Group 2	Itanhangá	39.0	Group 3

Table 5.b. Municipality groupings, municipality name, and group number

2. 1. 2. Share of municipal area cleared (Figure 5.5 in the chapter)

Relying on the MapBiomas v.3.0 dataset (version downloaded on October 26, 2018) we classified the share of municipal area converted to anthropized use (i.e. any other use than native vegetation or non-forest vegetation). Here are the steps followed for classifying the land cover transitions:

1. We used the "Transicão" sub-dataset
2. We selected land classes for Mato Grosso municipalities only
3. Relying on land classes of level 1, we:
    a. Filtered FROM LEVEL-1 classes 1 (floresta) and 2 (formaçao natural nao florestal)
    b. Filtered TO LEVEL-1 classes 3 (Agropecuaria), 4 (Area nao Vegetada), 5 (Corpo d'Agua), 6 (Nao observado)

This showed the conversion of forests and non-forest vegetation to anthropized uses or others, but surely ignored any regeneration process, one limitation of this classification. Since we are only interested in the *trend* in overall clearing of native vegetation at the municipal level, we think that this classification will not result in large classification errors despite its shortcomings.

4. We then created a formula to sum up the lines within a same year and generate estimates of land clearing at the municipal level

2. 2. DATASET DETAILS

2. 2. 1. Description of dataset (a)

The sample of dataset (a) includes 104 soybean producers with whom the authors conducted semi-structured interviews between February and June 2017. The study received an exempt type IRB approval (n° 1604625766) and oral consent was gathered from participants prior to starting the questionnaire. The participation in the interviews was broad although farmers were difficult to contact because of their busy schedules and constant movement. As a result, the non-response rate was of 46.9%, mostly because agreeing on mutually convenient date and time to meet prove challenging (only 22 of the 196 farmers contacted verbally refused to participate in the study) (see Table 3.). Table 4. shows the sample's area breakdown. Most farmers in the sample controlled (own or rent) an area between 5,000 and 10,000 hectares, and still directly operate their farms, at least partially. The total geographical area covered by the sample is nearly 1 million hectares (972,977 hectares to be exact).

Area (in hectares: ha)	Total area owned	Total area rented	Total area controlled
< 2,000ha	15	85	6
2,000 – 5,000 ha	32	6	36
5,000 – 10,000 ha	31	4	32
10,000 – 20,000 ha	12	2	13
> 20,000 ha	12	1	14
No information	2	6	3
TOTAL	**104**	**104**	**104**

Table 5.c. Sample breakdown as per area owned, rented, and controlled (i.e. adding owned and rented areas)

Municipality	Region	Number of interviews	Number contacted	Response rate
Nova Mutum	*Alto Teles Pires*	18	30	60.0%
Lucas do Rio Verde	*Alto Teles Pires*	13	36	36.1%
Sorriso	*Alto Teles Pires*	16	30	53.3%
Sinop	*Alto Teles Pires*	15	17	88.2%
Campo Novo do Parecis	*Chapada dos Parecis*	14	26	53.8%
Sapezal	*Chapada dos Parecis*	15	36	41.6%
Campos de Júlio	*Chapada dos Parecis*	13	21	61.9%
TOTAL	-	**104**	**196**	**53.1%**

Table 5.d. Farmers interviewed per municipality, region, and report on the response rate.

From this dataset we derived:

- **Figure 5.7 showing the land-use change within 56 properties**

The property boundaries used in this study were reported by the interviewees themselves. At the end of each interview, interviewees were asked whether they would accept to draw the boundaries of the farm used as a reference for the interview. Since some landowners may own or rent several properties, the "property of reference" was the landowner's property that would meet all or most of the following conditions, ranked in order of importance: (1) first property acquired in the area; (2) larges property owned (and not rented); (3) property located in the municipality where the

landowner resides. The rationale for such criteria was to get data on the property which represented the longest history of land-use the landowner was responsible for, in order to match as well as possible land-use history with interview data. In total 65 property boundaries representing the landholdings of 56 landowners were gathered.

The per 5-year land-use classification relied on visual classification of Landsat TM 5 and OLI-TIRS 8 images selected to eliminate all cloud cover and with a narrow time range (dry season from May to September). The choice of a visual classification was justified by the need to be very precise, given that unsupervised classification errors tend to be around 10% or more (Arvor et al. 2012; Welch et al. 2013; Jepson 2005; Risso et al. 2012; Rudorff et al. 2011).

- **Annex 4 showing the adoption of good agricultural practices by producers**

The examined variables were derived both directly from answers to the semi-structured questionnaires and indirectly from the researcher's classification and interpretation of respondents' answers. The questions were not designed to directly measure the adoption of a set of practices already defined informally by the researcher or officially by any relevant public institutions, contrary to other studies. Rather, following an ethnographic approach, the choice was made to let the farmers express their own views on what a good agricultural practices (GAPs) meant to them, allowing the identification of a broader set of practices than usually identified by public agencies (29 in total, see Figure 4.1). In this study, measures of the adoption of GAPs were derived from 3 questions where farmers were asked about (1) how they define GAP; (2) how they define a conservation practice; (3) examples of GAPs they implement on their property. This technique allowed the identification of as many as 29 practices.

2. 2. 2. Description of dataset (b)

Municipality	Stakeholder category	Year of arrival in MT	Min. to max. planted area (ha)	
			Soybean	Maize
Sinop	Producers: 6	1980 ~ 2003	1000 ~ 7500	500 ~ 5250
	University (UFMT): 2	-	-	-
	Government (Embrapa): 2	-	-	-
	Agribusiness (trader): 1	-	-	-
	Agribusiness (Retailer): 1	-	-	-
	Producer's association (Rural Union): 1	-	-	-
Ipiranga do Norte	Producers: 1	1999	860	500
Sorriso	Producers: 2	1977	840~1335	840~1290
	Civil society (CAT): 1	-	-	-
Lucas do Rio Verde	Producers: 1	1982	1200	600
Campo N. dos Parecis	Producers: 2	1981 ~ 1985	500~8000	500~4000
Canarana	Producers: 3	1977 ~ 2008	1200 ~ 7000	400 ~ 4000
	Government (SMA): 1	-	-	-
Rondonópolis	Producers: 3	1980 ~ 1982	150 ~ 7000	150 ~ 4000
Cuiabá (state capital)	Government (IMEA, SENAR): 2	-	-	-
	Producer's association (Aprosoja): 1	-	-	-
	Agribusiness (trader and producers): 1	1980	155550	66245

Table 5.e. List of stakeholders interviewed during fieldwork in Mato Grosso State, Brazil, in 2017 (co-authors' dataset)

Production Strategies	Rationale	Associated practices	Risks	Period
A. Expansionist Strategy	Increase area planted at property scale	Slash-and-burn	**Environmental** Deforestation **(+ risk)** Drought **(+ risk)** **Financial** Low productivity **(+ risk)**	1980-2005
B. Property-level intensification strategy	Increase output production while reducing costs at property scale (with minimum investment in soils). What matters is the discrepancy between costs and benefits at the property-level	Double cropping No till	**Environmental** Deforestation **(+/- risk)** Soil exhaustion **(- risk)** Agrochemicals increase **(+ risk)** Drought **(+ risk)** **Financial** Medium productivity **(- risk)** Price volatility **(+/- risk)**	1990-2005
C. Plot-level intensification strategy	Increase output production while reducing costs at the plot scale. It can be both high(costs)-high(production) or low-low models of production at the hectare-level. Short-term profitability	Precision agriculture Biological control of pests On-farm seeds production	**Environmental** Deforestation **(- risk)** Soil exhaustion **(+ risk)** Agrochemicals increase **(+/- risk)** **Financial** High productivity **(- risk)** or Low productivity **(+ risk)** Price volatility **(+ risk)**	2005-…
D. Commercialization strategy	Increase profitability through better deals and timing in purchase of inputs or sale of outputs. Focus away from maximum productivity.	Crop storage Crop dryer Purchasing groups and cooperatives Futures and options contracts Certification Conventional soybean	**Environmental** Deforestation **(- risk)** Agrochemicals decrease **(-risk)** **Financial** Price volatility **(- risk)** Lower input costs **(-risk)** Premium price **(-risk)**	2000-…
E. Plot-level diversification strategy	Increase medium- and long- term profitability through recycling nutrients and preserve soil health. This is a focus that integrates "profitability per hectare" but instead extends the profitability horizon to medium- to long- term profitability	Crop rotation New crop varieties ILP, ILPF	**Environmental** Deforestation **(- risk)** Agrochemicals decrease **(-risk)** Soil exhaustion **(- risk)** **Financial** Lower input costs **(-risk)** Crop variety **(-risk)** Long-term planning **(-risk)**	2005-…

Table 5.f. Categories of production strategies, rationale, associated practices and risks

Municipality	Ranking in 2016	Production in 2016 (t)	Percentage of state production
Sorriso	1	1,771,200	6.7
Nova Ubiratã	2	1,497,200	5.7
Sapezal	3	1,171,410	4.5
Nova Mutum	4	1,165,350	4.4
Campo Novo do Parecis	5	1,162,800	4.4
Diamantino	6	926,100	3.5
Querência	7	910,800	3.5
Primavera do Leste	8	738,450	2.8
Lucas do Rio Verde	9	711,000	2.7
Campo Verde	10	671,615	2.6
Brasnorte	11	664,440	2.5
Canarana	12	626,940	2.4
São Félix do Araguaia	13	615,859	2.3
Campos de Júlio	14	580,566	2.2
Itiquira	15	540,000	2.1
Nova Maringá	16	475,200	1.8
Tapurah	17	459,000	1.7
Ipiranga do Norte	18	456,412	1.7
Santa Rita do Trivelato	19	452,760	1.7
Porto dos Gaúchos	20	437,760	1.7
Paranatinga	21	420,000	1.6
Sinop	22	403,200	1.5
Vera	23	383,520	1.5
Tabaporã	24	378,000	1.4
Gaúcha do Norte	25	359,100	1.4
Santo Antônio do Leste	26	330,000	1.3
São José do Rio Claro	27	319,499	1.2
Água Boa	28	319,200	1.2
Feliz Natal	29	310,200	1.2
Tangará da Serra	30	303,000	1.2
Bom Jesus do Araguaia	31	301,941	1.1
Cláudia	32	290,460	1.1
Alto Garças	33	273,600	1.0
Santa Carmem	34	270,000	1.0
Rondonópolis	35	244,800	0.9
Itanhangá	36	229,320	0.9
Novo São Joaquim	37	221,128	0.8
São José do Xingu	38	219,450	0.8
Comodoro	39	208,080	0.8
Guiratinga	40	195,840	0.7
Total Top 40	**-**	**22,015,200**	**83.8**
Total Mato Grosso	**-**	**26,277,303**	**100**

Table 5.g. Table of top 40 soybean producers in 2016 (Production data from IBGE's Municipal Agricultural Production)

Municipality	Score	Group number	Municipality	Score	Group number
Primavera do Leste	4.0	Group 1	São José do Rio Claro	22.3	Group 2
Itiquira	5.7	Group 1	Tapurah	22.7	Group 2
Rondonópolis	5.7	Group 1	Comodoro	24.0	Group 2
Campo Verde	6.3	Group 1	Brasnorte	24.3	Group 2
Lucas do Rio Verde	7.7	Group 1	Querência	24.3	Group 2
Campo Novo do Parecis	8.0	Group 1	Nova Ubiratã	25.7	Group 2
Diamantino	8.0	Group 1	Santa Rita do Trivelato	26.0	Group 2
Alto Garças	9.0	Group 1	São Félix do Araguaia	26.0	Group 2
Guiratinga	10.0	Group 1	Gaúcha do Norte	26.7	Group 2
Sorriso	13.3	Group 1	Sinop	26.7	Group 2
Água Boa	14.0	Group 1	Nova Maringá	27.7	Group 3
Nova Mutum	15.0	Group 1	Bom Jesus do Araguaia	28.0	Group 3
Sapezal	15.0	Group 1	Feliz Natal	29.7	Group 3
Novo São Joaquim	16.0	Group 1	Cláudia	30.3	Group 3
Canarana	17.0	Group 1	Vera	31.0	Group 3
São José do Xingu	18.0	Group 1	Santa Carmem	31.3	Group 3
Tangará da Serra	18.0	Group 1	Porto dos Gaúchos	32.7	Group 3
Campos de Júlio	19.7	Group 1	Ipiranga do Norte	34.0	Group 3
Santo Antônio do Leste	21.3	Group 2	Tabaporã	34.3	Group 3
Paranatinga	21.7	Group 2	Itanhangá	39.0	Group 3

Table 5.h. Municipality groupings, municipality name, and group number

3. CHAPTER 6.

Tables 6.a and 6.b list the aspects mentioned by interviewees as coded in English (leftmost column) with a brief description of their meaning (central column) and examples of what the statement where in Portuguese (rightmost column).

Positive aspects	Description	Statement example
Production	Deforestation is positive because it is made in the purpose of producing food (crops or meat) or occupying land "wisely" by choosing the best soils to plant crops. It either refers to the role of providing foods for Brazilian people or for the world in general. It also contributes to **food security**.	"ocupação econômica do solo" (ITW n°016) "Alimentos para o mundo" (ITW n°020) "é necessidade para produzir alimentos (dentro das limites da lei)" (ITW n°007) "gera um solo para produção de lavoura ou pecuaria" (ITW n°028) "necessidade para a segurança alimentar" (ITW n°057) "desmatamento de solo de alta potencial agrícola para produçao" (ITW n°083)
Jobs	Deforestation is positive because it brings about the creation of new jobs as agricultural activities expand	"gerar emprego" (ITW n°049)
Development (economic & social; municipal & local)	Deforestation is positive because it fosters general economic and social development at the municipal and state levels (schools, hospitals, etc.). It creates jobs, tax revenues for the municipality or state, brings about infrastructures (roads, bridges, etc.). Includes also improvements in labor conditions, etc.	"desenvolvimento da região dentro dos limites aceitadas" (ITW n°009) "pagando imposto" (ITW n°054)
Brazilian development[305] (coded "Brazilian")	Deforestation is positive because it creates economic development for the nation in the form of agricultural expansion or improvements in the balance of payments with exportations	"leader em produção de commodities e fornecedor de alimentos" (ITW n° 008) "agronegócio ajuda a balance comercial" (ITW n°025)
Profitability	Deforestation is positive because it is the only way to improve or increase the total economic rent of the farm, or it helps valuing the property. It includes also when farmers referred to the development of their own family	"Você não consegue aumentar a renda menos ter que desmatar" (ITW n°011) "Crescimento econômico da fazenda" (ITW n°040) "incorporação imobiliária (valoriza a terra)" (ITW n°078) "manutenção e desenvolvimento da família" (ITW n°007)
Forest management	Deforestation is positive when it is done within a forest management plan	"Manejo florestal" (ITW n°021) "derrubar com sustentabilidade, derrubar para uma coisa nobra" (ITW n°014)
Species Improvement	Deforestation is positive because agriculture contributes to aggrandize the food base of local animal species	"melhoramento de alimentos da bicharada (patos, ...)" (ITW n°023)
Positive Climate	Deforestation is positive because, according to the interviewee, it creates a denser vegetation	"com soja-milho a área de cobertura verde é maior que o cerrado" (ITW n°022)

[305] Why having two categories for development? Because farmers demonstrated throughout the interviews that they distinguished the social and economic development concerning their municipality and the state of Mato Grosso from the larger-scale goals of Brazilian development (which consisted in their mind of improving the economic situation of Brazil).

	cover than natural vegetation contributing to mitigate local or global climate changes	"constante ciclo soja milho gera uma fotossíntese que o cerrado nao tinha" (ITW n°028)
Legal deforestation (coded "legal")	Deforestation is positive when it is done within the environmental laws	"Conseguir licenças e respeitar as leis" (ITW n°014)
Others	Other aspects: Better control of land Wood extraction Opportunity	"domínio mais fácil da terra" (ITW n°025) "approvamento de madeira" (ITW n°048) "Unico lugar do mundo onde tem 3 safras" (ITW n°060)

Table 6.a. List of positive aspects to deforestation as reported by the interviewee, and examples of quotes that show how they evoked such aspects

Negative aspects	Description	Statement example
Improper use	Deforestation is negative when it occurs on areas that are less suitable for agriculture than other fertile areas, or in the words of farmers, deforestation that does not follow any criteria	"desmatamento sem critério tem impacto grande na natureza" (ITW n°009) "abrir as áreas arenosas, quais nao eram boas para agricultura" (ITW n°046)
No use	Deforestation is negative when the cleared area is left unused after the event, like when the area is only used for wood extraction for instance	"Teve muitas áreas que forma desmatadas so pela madeira, não faz sentido" (ITW n°048)
Rivers	Deforestation is negative when it destroys riparian forest areas protecting springs, rivers (e.g. APPs), and affects water resources and quality in general	"desmatamento da beira dos rios, garimpos, diminua o numero de peixes" (ITW n°010) "desde que é desmatamento ilegal, nas cabeceiras das aguas" (ITW n°049)
Erosion	Deforestation is negative because it creates soil erosion due to the absence of vegetation cover – it can be both caused by water runoff (water erosion) or by wind (air erosion)	"destruí a flora, fauna, expor o solo" (ITW n°038) "expõe o solo as agressões da própria natureza" (ITW n°056) "aumento de vento, tira proteçao" (ITW n°093)
Biodiversity	Deforestation is negative because it leads to destroying natural habitats of animal and vegetal species (e.g. "fauna e flora")	"limita a área de atuação dos animais" (ITW n°014) "redução de abelha, polinização" (ITW n°040)
Pollution	Deforestation is negative because agriculture uses chemicals which contaminates the environment; or creates more truck traffic	"contaminação por adubo química" (ITW n°031) "contaminação do solo" (ITW n°076)
Global Climate	Deforestation is negative because it contributes to emit greenhouse gases (GHGs) that further global climate change	"Emissão de carbono e poluição" (ITW n°010) "fica na duvida de interferir com clima" (ITW n°036)
Local Climate	Deforestation is negative because it changes the rainfall pattern locally and regionally, and may cause local warming and droughts	"desregulamento das chuvas" (ITW n°027)
Illegal deforestation (coded "illegal")	Deforestation is negative when it is done without an environmental license or without respecting the legal requirements of native vegetation cover. This category also includes statements of farmers who think that deforestation is not sanctioned well enough. For some, deforestation is negative because of the risk of getting sanctioned and fined (see e.g. ITW n°078)	"distorções do desmatamento ilegal (garimpeiros, exploração de madeira)" (ITW n°026) "ilegalidade, se paga um preço alto por isso" (ITW n°078)
Disturbance	Deforestation is negative when it creates a disturbance in the environment, or unbalance the previous state of the ecosystem.	"desequilibro ecologico" (ITW n°002)
Others	Other negative aspects of deforestation include: Increase in pests Bad international reputation Fires Increase economic competition Forget future generations Pay taxes for the cleared area Lack of control over animals	"aumentaçao das pragas" (ITW n°037) "muito mal visto no nivel internacional" (ITW n°013) "queimas" (ITW n°028) "aumenta a oferta do produto então baixa o preço" (ITW n°061) "não pensar em futuras geraçoes" (ITW n°078) "cobram o imposto territorial" (ITW n°079) "o descontrole da fauna" (ITW n°086)

Table 6.b. List of positive aspects to deforestation as reported by the interviewee, and examples of quotes that show how they evoked such aspects

Practice	Description	Objective	Keywords in ITWs	Coding
Soil-related practices				
No till systems	No till systems in Mato Grosso consists of (1) no tilling of the soil; (2) leaving straw cover after the last harvest, during the interseason). Note: It is usually used in combination with cover crops and bench terraces to maximize benefits	Reduce soil erosion / Restore soil fertility	"plantio direto"[306]; "plantio na palha"	*notill*
Straw generation	Refers to producing straw cover after harvest (with corn)	Reduce soil erosion / Restore soil fertility	"palhada"	*straw*
Cover crop	Cover crop in between two harvest years, or combination of a cover crop with an actual crop (e.g. *crotalaria* grass with corn for integrated crop-livestock systems)	Reduce soil erosion / Restore soil fertility	"cobertura do solo"; "consorcio"	*covercrop*
Terrace farming	Consists of creating bench terraces to reduce rain wash speed in areas with slope and practice contour planting	Reduce soil erosion	"terraço de base larga" "curvas de nível"	*bterrace*
Micro-basins	Refers to the creation of a topography respecting micro-basin features and limiting water erosion on the fields	Reduce soil erosion	"micro bacias"; "canalização das aguas"	*microbasin*
Soil correction	Adding limestone to the soil to reduce acidity, and other practices to improve soil quality for crop production	Restore soil fertility/ Reduce soil acidity	"correção de solo"; "perfil do solo"	*soilcorrec*
Soil compaction	Plant crops to avoid soil compaction or use machines to alleviate the soil compaction	Restore soil fertility	"descompactar o solo"	*soilcompac*
Crop rotation	Involves leaving land plots without soybean or corn for a few years every 2-3 years in order to restore the soil. Looks like shifting cultivation but with a filler crop	Restore soil fertility	"rotaçao de cultura"	*rotation*
Chemical-related practices				
Biological products	Use of organic-based fertilizers or pesticides	Restore soil fertility / Reduce toxicity	"adubo orgânico (galinha, liquido de suínos)" ; "adubos biológicos"; "controle biológicos"	*biological*
Correct chemical use	Consists of efforts to (1) reduce applications and volumes of fertilizers, pesticides and fungicides used; (2) choose the least toxic products available "blue" or "green ribbon", (3)	Reduce toxicity	"correta utilização dos produtos"; "evitar a	*chemical*

[306] The full no-till technique (in Portuguese, "plantio direto") actually involves no soil revolving along with cover crops and crop rotation. However, most farmers in MT do not practice crop rotation but crop succession (planting different crops within a same year as opposed to different years). Nonetheless, they commonly refer to the practice as "plantio direto" although this is technically incorrect. The correct term for this practice is "plantio na palha". Knowing this common mistake I interpreted both Portuguese terms to be the no-till technique and created a separate category for crop rotation for when farmers intentionally signal that they actually do more than crop succession.

	use products correctly, in the periods and dosage recommended by the manufacturer; (4) use only products approved by the Ministry of Agriculture (5) clean up equipment and machines used for chemical applications in a proper way; (6) avoid any chemical leaching		lixiviação"; "diminuição dos agrotóxicos"	
Precision agriculture	Refers to a set of practices to improve the accuracy of agriculture based on each plot's characteristics (e.g. calculating the amount of inputs required for each specific plot, avoiding over- or under-loads)	Improve production/ Reduce toxicity	"agricultura de precisão"	*precisionag*
Recycling	Recycling packages of chemicals, including triple washing of packages. Also refers to the disposal and/or recycling of filters, oils, etc. instead of burning them	Reduce toxicity	"cuidar do lixo toxico" ; "reciclagem de filtros, óleos"	*recycling*
Integrated Pest Management (IPM)	Refers to a particular set of pest management techniques involving regular monitoring of crop infestation, etc.	Reduce toxicity (along with reduced risk in pests)	"manejo integrado das pragas"; "uso de pesticidas no tempo"; "olhar a lavoura antes de decidir de fazer uma aplicação"; "monitoramento"	*ipm*
Biotechnology	Use of genetically-modified organisms (GMOs) as a way to reduce agrochemical use	Reduce toxicity	"transgénicos porque ajuda reduzir a quantidade de defensivos" (ITW n°009) "uso de biotecnologia"	*biotech*
Conservation-related practices				
Area of Permanent Preservation	Protection of riparian forest areas, as well as areas near hills, as per Forest Code criteria	Conserve forests	"APP"; "cuidar dos afluentes"	*app*
Legal Reserve	Protect a percentage of native vegetation of the property as per Forest Code criteria	Conserve forests	"Reserva legal"; "RL"	*lr*
Selective land clearing	Clearing within the legal limits and not clearing sandy areas (that are poorly suited for crop production)	Optimize land use	"abrir área com boa aptidão do solo" (ITW n°006)	*selective*
Forest restoration	Planting or forest restoration activities, following a reforestation plan set by the law (PRA)	Increase forest cover	"recuperação das áreas degradadas"	*restoration*
Ecological corridors	Leaving or restoring bands of vegetation connecting two areas of distant vegetation in order to allow for animals crossing and biodiversity connectivity	Preserve biodiversity	"corredores"	*corridors*
Fire avoidance	Avoid fires on the property during the dry season	Conserve soil fertility	"não queimar"	*fire*
Animal hunting	Avoid animal hunting	Preserve biodiversity	"caça"	*animal*

Production-related practices				
Crop-Livestock Integration (ILP) and Crop-Cattle-Forest Integration (ILPF)	ILP is a practice promoted by EMBRAPA and according to which production systems should mix cattle-ranching and crop cultivation. ILPF is the same system with the addition of forestry (usually eucalyptus)	Production intensification / optimization	"integração lavoura-pecuária"; "ILP"; "integração lavoura-pecuária-floresta"; "ILPF"	*ilp*
Crop succession	Refers to double-cropping systems consisting of planting soybean as a first harvest and corn as a second, within the same year.	Increase production	"duas safras"	*succession*
Crop irrigation	Use irrigation for crop rotation or third harvest	Increase production	"pivô"	*irrigation*
Credit	Rely on credit to fund production and take opportunity of the interesting interest rates	Production optimization	"juros suave"	*credit*
Storage	Use storage facilities for harvest and sell at better market conditions	Production optimization	"armazéns"	*storage*
Water-related practices				
Water savings	Refers to the practice of reducing water use	Reduce water use	"evitar o desperdício seja de água (...)"	*watersavings*
Water wells	Refers to the practice of using water from "artesian" wells rather than streams intake for mixing water with agrochemicals	Reduce water use (from streams)	"poço artesiano"	*watersupply*
Water tank	Refers to the practice of having a rainwater tank to produce the water that needs to be mixed with chemicals, thus avoiding well contamination	Reduce water use from streams	"tanque de agua"; "captação da chuva"	*watertank*

Table 6.c. Summary of GAP categories.

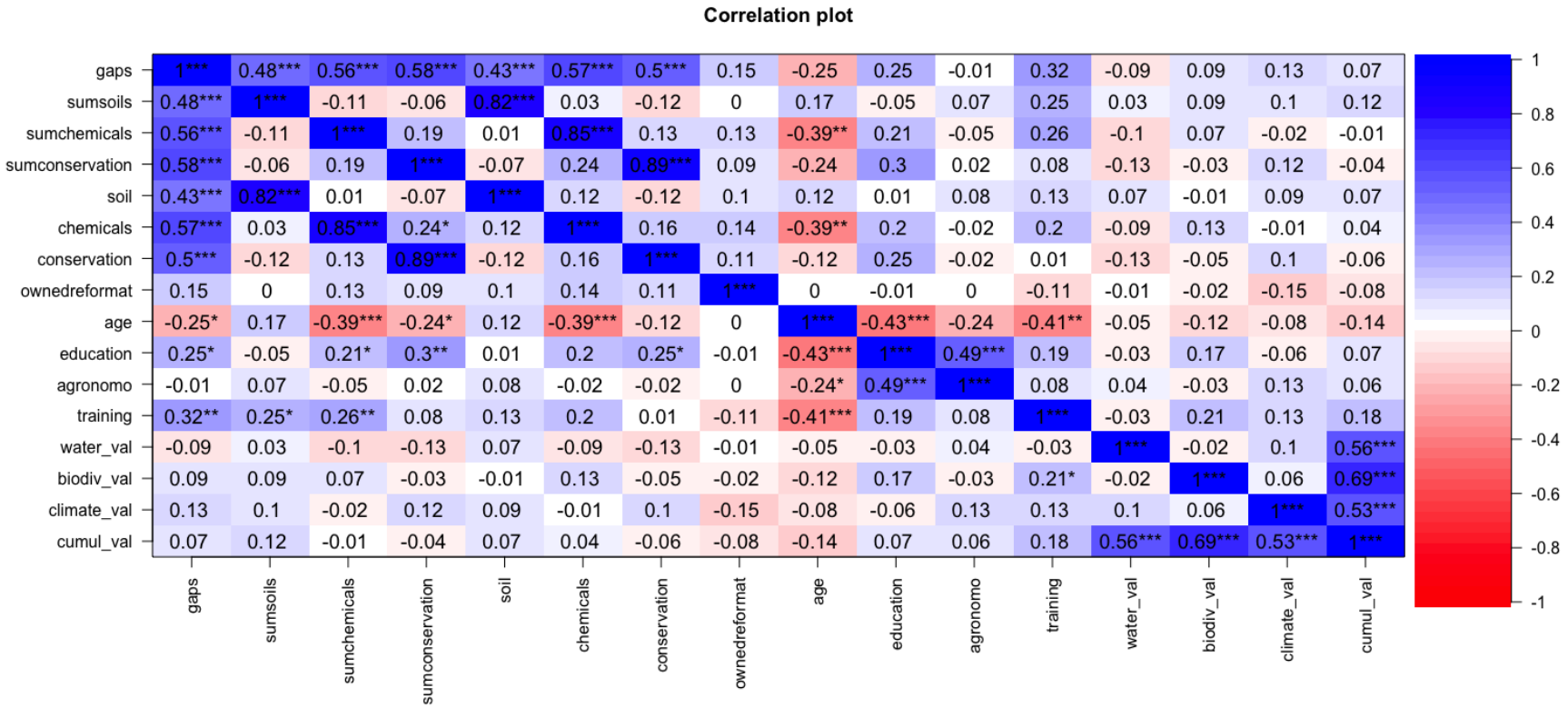

Figure 6.a. Plot showing the Pearson correlations between variables of interests for the analysis. The stars next to the number show p-value significance levels of * (<0.05) ** (<0.01) ***(<0.005). Note: These significance levels are different than those used in the statistical analysis.

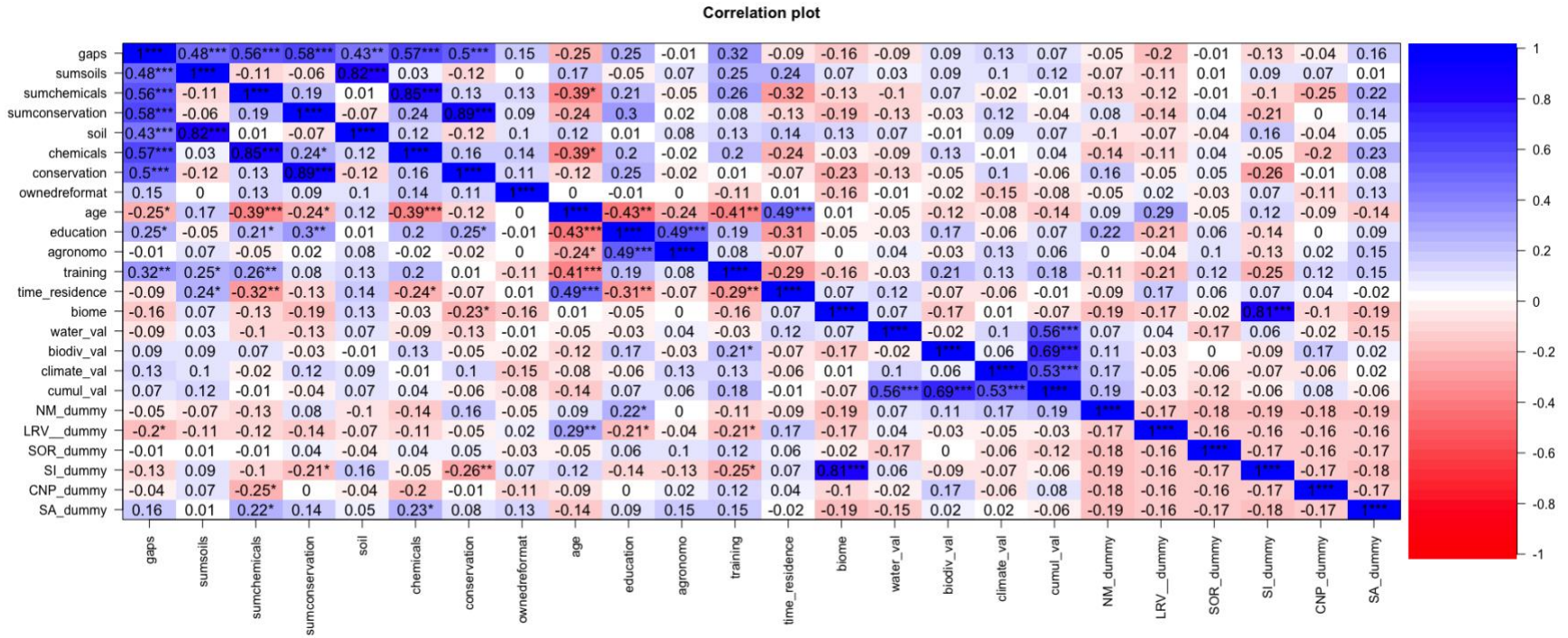

Figure 6.b. Plot showing the Pearson correlations between variables included in the dataset. This plot includes variables for time of residence, biome location, and municipality location. The stars next to the number show p-value significance levels of * (<0.05) ** (<0.01) ***(<0.005). Note: These significance levels are different than those used in the statistical analysis.

GAPs adoption

	Dependent variable:			
	GAPs			
Models	Values	Education	Agronomist	Edu&Agro
	(1)	(2)	(3)	(4)
Intercept	**1.098**	**0.887**	**1.278**	**0.881**
	p = 0.000* **	**p = 0.024** **	**p = 0.0004*** **	**p = 0.022** **
Water	-0.156	-0.161	-0.168	-0.156
	p = 0.285	p = 0.278	p = 0.257	p = 0.294
Biodiversity	0.100	-0.013	-0.009	-0.071
	p = 0.400	p = 0.915	p = 0.945	p = 0.580
Climate	0.236	0.259	0.251	0.351
	p = 0.161	p = 0.137	p = 0.151	p = 0.052*
Area (100ha)		0.001	0.001	0.001
		p = 0.071*	p = 0.063*	p = 0.054*
Age		-0.006	-0.011	-0.007
		p = 0.341	p = 0.072*	p = 0.238
Time Residence		0.007	0.007	0.009
		p = 0.312	p = 0.330	p = 0.187
Biome		-0.170	-0.164	-0.167
		p = 0.362	p = 0.379	p = 0.371
Training		0.296	0.309	0.305
		p = 0.031**	p = 0.025**	p = 0.026**
Education		0.220		0.359
		p = 0.104		p = 0.017**
Agronomist			-0.161	-0.354
			p = 0.322	p = 0.049**
Observations	99	99	99	99
Log Likelihood	-191.529	-182.441	-183.260	-180.434
Akaike Inf. Crit.	391.059	384.882	386.521	382.867

Note: *p<0.1; **p<0.05; ***p<0.01

Table 6.d. The effect of pro-environmental values on the number of GAPs adopted by producers. The p-value thresholds are indicated on the table.

Soil-related practices adoption

	Dependent variable:			
	Soil-related practices (sum)			
Models	Values	Education	Agronomist	Edu&Agro
	(1)	(2)	(3)	(4)
Intercept	**-0.295**	**-2.975**	**-3.123**	**-3.059**
	p = 0.290	**p = 0.00004*****	**p = 0.00001*****	**p = 0.00003*****
Water	0.075	-0.017	-0.026	-0.025
	p = 0.787	p = 0.953	p = 0.928	p = 0.931
Biodiversity	0.193	0.021	0.066	0.083
	p = 0.364	p = 0.925	p = 0.773	p = 0.720
Climate	0.264	0.322	0.259	0.242
	p = 0.369	p = 0.283	p = 0.393	p = 0.430
Area (100ha)		0.0004	0.0004	0.0005
		p = 0.628	p = 0.593	p = 0.553
Age		0.023	0.026	0.025
		p = 0.031**	p = 0.017**	p = 0.020**
Time Residence		0.032	0.030	0.029
		p = 0.024**	p = 0.034**	p = 0.043**
Biome		0.402	0.417	0.419
		p = 0.153	p = 0.139	p = 0.138
Training		0.972	0.979	0.986
		p = 0.0002***	p = 0.0002***	p = 0.0002***
Education		0.065		-0.111
		p = 0.775		p = 0.688
Agronomist			0.333	0.408
			p = 0.226	p = 0.222
Observations	99	99	99	99
Log Likelihood	-126.678	-114.721	-114.066	-113.985
Akaike Inf. Crit.	261.356	249.442	248.132	249.970

Note: *p<0.1; **p<0.05; ***p<0.01

Table 6.e. The effect of pro-environmental values on the total of soil-related GAPs adopted by producers. The p-value thresholds are indicated on the table.

Chemicals-related practices adoption

	Dependent variable:			
	Chemicals-related practices (sum)			
Models	Values	Education	Agronomist	Edu&Agro
	(1)	(2)	(3)	(4)
Intercept	**-0.022**	**1.279**	**1.476**	**1.203**
	p = 0.932	**p = 0.083***	**p = 0.019****	**p = 0.094***
Water	-0.221	-0.235	-0.239	-0.222
	p = 0.388	p = 0.375	p = 0.363	p = 0.399
Biodiversity	0.139	0.007	-0.031	-0.066
	p = 0.520	p = 0.975	p = 0.890	p = 0.776
Climate	-0.044	-0.086	-0.023	0.046
	p = 0.897	p = 0.807	p = 0.947	p = 0.900
Area (100ha)		0.001	0.001	0.001
		p = 0.284	p = 0.217	p = 0.195
Age		-0.023	-0.028	-0.025
		p = 0.043**	p = 0.013**	p = 0.032**
Time Residence		-0.011	-0.009	-0.007
		p = 0.379	p = 0.479	p = 0.550
Biome		-0.204	-0.170	-0.171
		p = 0.566	p = 0.634	p = 0.631
Training		0.221	0.252	0.256
		p = 0.375	p = 0.316	p = 0.305
Education		0.018		0.205
		p = 0.944		p = 0.466
Agronomist			-0.390	-0.488
			p = 0.203	p = 0.143
Observations	99	99	99	99
Log Likelihood	-118.268	-109.935	-109.062	-108.797
Akaike Inf. Crit.	244.536	239.870	238.123	239.594

Note: *p<0.1; **p<0.05; ***p<0.01

Table 6.f. The effect of pro-environmental values on the total of chemicals-related GAPs adopted by producers. The p-value thresholds are indicated on the table.

Conservation-related practices adoption

	Dependent variable:			
	Conservation-related practices (sum)			
	Values	Education	Agronomist	Edu&Agro
	(1)	(2)	(3)	(4)
Intercept	**-0.028**	**0.421**	**1.583**	**0.254**
	p = 0.917	**p = 0.590**	**p = 0.024****	**p = 0.734**
Water	-0.430	-0.473	-0.498	-0.487
	p = 0.121	p = 0.100*	p = 0.081*	p = 0.090*
Biodiversity	-0.110	-0.295	-0.267	-0.444
	p = 0.647	p = 0.229	p = 0.286	p = 0.086*
Climate	0.479	0.658	0.570	0.915
	p = 0.137	p = 0.052*	p = 0.090*	p = 0.012**
Area (100ha)		0.001	0.001	0.001
		p = 0.336	p = 0.448	p = 0.239
Age		-0.017	-0.031	-0.018
		p = 0.135	p = 0.010***	p = 0.118
Time Residence		0.006	0.004	0.010
		p = 0.690	p = 0.757	p = 0.474
Biome		-0.976	-0.952	-0.991
		p = 0.042**	p = 0.047**	p = 0.039**
Training		-0.200	-0.150	-0.146
		p = 0.462	p = 0.587	p = 0.589
Education		0.741		1.066
		p = 0.011**		p = 0.001***
Agronomist			-0.206	-0.750
			p = 0.520	p = 0.036**
Observations	99	99	99	99
Log Likelihood	-111.549	-101.575	-104.734	-99.158
Akaike Inf. Crit.	231.097	223.150	229.468	220.316

Note: *p<0.1; **p<0.05; ***p<0.01

Table 6.g. The effect of pro-environmental values on the total of conservation-related GAPs adopted by producers. The p-value thresholds are indicated on the table.

Soil-related practices binary adoption

	Dependent variable:			
	Soil-related practices (0-1)			
	Values	Education	Agronomist	Edu&Agro
	(1)	(2)	(3)	(4)
Intercept	**-0.102**	**-4.971**	**-4.284**	**-4.924**
	p = 0.841	**p = 0.005*****	**p = 0.005*****	**p = 0.005*****
Water	0.312	0.359	0.329	0.357
	p = 0.545	p = 0.524	p = 0.556	p = 0.526
Biodiversity	-0.060	-0.079	0.011	-0.048
	p = 0.883	p = 0.862	p = 0.980	p = 0.917
Climate	0.546	0.779	0.569	0.704
	p = 0.404	p = 0.283	p = 0.423	p = 0.341
Area (100ha)		0.003	0.003	0.003
		p = 0.075*	p = 0.096*	p = 0.082*
Age		0.046	0.041	0.046
		p = 0.056*	p = 0.072*	p = 0.053*
Time Residence		0.035	0.028	0.033
		p = 0.210	p = 0.307	p = 0.245
Biome		1.200	1.187	1.206
		p = 0.068*	p = 0.070*	p = 0.067*
Training		1.391	1.371	1.395
		p = 0.011**	p = 0.012**	p = 0.011**
Education		0.649		0.486
		p = 0.211		p = 0.414
Agronomist			0.644	0.368
			p = 0.271	p = 0.586
Observations	99	99	99	99
Log Likelihood	-67.601	-60.482	-60.676	-60.333
Akaike Inf. Crit.	143.203	140.965	141.352	142.667

Note: *p<0.1; **p<0.05; ***p<0.01

Table 6.h. The effect of pro-environmental values on whether producers have adopted at least one soil-related GAPs. The p-value thresholds are indicated on the table.

Chemicals-related practices binary adoption

	Dependent variable:			
	Chemicals-related practices (0-1)			
	Values	Education	Agronomist	Edu&Agro
	(1)	(2)	(3)	(4)
Intercept	**0.505**	**4.065**	**4.602**	**4.159**
	p = 0.346	**p = 0.014****	**p = 0.004*****	**p = 0.015****
Water	-0.460	-0.553	-0.571	-0.573
	p = 0.404	p = 0.361	p = 0.351	p = 0.353
Biodiversity	0.539	0.413	0.419	0.346
	p = 0.195	p = 0.392	p = 0.379	p = 0.478
Climate	-0.053	-0.173	-0.126	-0.030
	p = 0.935	p = 0.810	p = 0.860	p = 0.967
Area (100ha)		0.003	0.003	0.003
		p = 0.131	p = 0.139	p = 0.142
Age		-0.066	-0.073	-0.070
		p = 0.008***	p = 0.004***	p = 0.006***
Time Residence		-0.016	-0.016	-0.011
		p = 0.607	p = 0.596	p = 0.725
Biome		0.200	0.159	0.149
		p = 0.748	p = 0.797	p = 0.811
Training		0.183	0.135	0.125
		p = 0.724	p = 0.797	p = 0.814
Education		0.036		0.448
		p = 0.945		p = 0.469
Agronomist			-0.680	-0.955
			p = 0.283	p = 0.198
Observations	99	99	99	99
Log Likelihood	-65.549	-55.956	-55.374	-55.111
Akaike Inf. Crit.	139.097	131.912	130.749	132.222

Note: *p<0.1; **p<0.05; ***p<0.01

Table 6.i. The effect of pro-environmental values on whether producers have adopted at least one chemicals-related GAPs. The p-value thresholds are indicated on the table.

Conservation-related practices binary adoption

	Dependent variable:			
	Conservation-related practices (0-1)			
	Values	Education	Agronomist	Edu&Agro
	(1)	(2)	(3)	(4)
Intercept	**0.412**	**0.438**	**2.435**	**0.347**
	p = 0.424	**p = 0.770**	**p = 0.074***	**p = 0.830**
Water	-0.751	-0.838	-0.811	-0.830
	p = 0.152	p = 0.142	p = 0.143	p = 0.153
Biodiversity	-0.248	-0.681	-0.486	-0.879
	p = 0.549	p = 0.157	p = 0.282	p = 0.083*
Climate	0.762	1.253	1.014	1.610
	p = 0.230	p = 0.088*	p = 0.141	p = 0.034**
Area (100ha)		0.001	0.001	0.002
		p = 0.393	p = 0.449	p = 0.331
Age		-0.014	-0.035	-0.018
		p = 0.530	p = 0.106	p = 0.458
Time Residence		0.018	0.008	0.027
		p = 0.520	p = 0.774	p = 0.351
Biome		-1.776	-1.642	-1.889
		p = 0.025**	p = 0.027**	p = 0.022**
Training		-0.414	-0.425	-0.440
		p = 0.426	p = 0.406	p = 0.432
Education		1.332		2.041
		p = 0.013**		p = 0.002***
Agronomist			-0.433	-1.604
			p = 0.451	p = 0.024**
Observations	99	99	99	99
Log Likelihood	-66.278	-58.229	-61.347	-55.450
Akaike Inf. Crit.	140.556	136.458	142.693	132.900

Note: *p<0.1; **p<0.05; ***p<0.01

Table 6.j. The effect of pro-environmental values on whether producers have adopted at least one conservation-related GAPs. The p-value thresholds are indicated on the table.

GAPs adoption – Cumulative values

	Dependent variable:			
	GAPs Adoption			
	Values	Education	Agronomist	Edu&Agro
	(1)	(2)	(3)	(4)
Intercept	**0.972**	**0.807**	**1.152**	**0.815**
	p = 0.000* **	**p = 0.035** **	**p = 0.001*** **	**p = 0.030** **
Cumulative Values	0.059	0.006	0.008	0.006
	p = 0.462	p = 0.941	p = 0.925	p = 0.944
Area (100ha)		0.001	0.001	0.001
		p = 0.111	p = 0.097*	p = 0.100*
Age		-0.005	-0.009	-0.006
		p = 0.376	p = 0.105	p = 0.284
Time Residence		0.006	0.005	0.007
		p = 0.413	p = 0.457	p = 0.309
Biome		-0.173	-0.170	-0.158
		p = 0.349	p = 0.357	p = 0.393
Training		0.318	0.326	0.320
		p = 0.019**	p = 0.017**	p = 0.018**
Education		0.203		0.294
		p = 0.129		p = 0.041**
Agronomist			-0.130	-0.266
			p = 0.412	p = 0.116
Observations	99	99	99	99
Log Likelihood	-193.065	-183.912	-184.722	-182.641
Akaike Inf. Crit.	390.130	383.823	385.444	383.281

Note: *p<0.1; **p<0.05; ***p<0.01

Table 6.k. The cumulative effect of pro-environmental values on the number of GAPs adopted by producers. The p-value thresholds are indicated on the table.

Soil-related practices adoption – Cumulative values

	Dependent variable:			
	Soil-related practices Adoption			
	Values	Education	Agronomist	Edu&Agro
	(1)	(2)	(3)	(4)
Intercept	**-0.363**	**-2.940**	**-3.145**	**-3.076**
	p = 0.135	**p = 0.00003*** **	**p = 0.00001*** **	**p = 0.00002*** **
Cumulative Values	0.181	0.092	0.090	0.095
	p = 0.206	p = 0.543	p = 0.545	p = 0.524
Area (100ha)		0.0003	0.0004	0.0004
		p = 0.697	p = 0.646	p = 0.589
Age		0.022	0.026	0.025
		p = 0.035**	p = 0.016**	p = 0.019**
Time Residence		0.029	0.028	0.027
		p = 0.031**	p = 0.041**	p = 0.051*
Biome		0.390	0.402	0.402
		p = 0.161	p = 0.149	p = 0.148
Training		0.954	0.974	0.987
		p = 0.0002***	p = 0.0001***	p = 0.0001***
Education		0.049		-0.129
		p = 0.831		p = 0.634
Agronomist			0.354	0.435
			p = 0.187	p = 0.174
Observations	99	99	99	99
Log Likelihood	-126.782	-115.089	-114.288	-114.173
Akaike Inf. Crit.	257.564	246.178	244.576	246.345

Note: *p<0.1; **p<0.05; ***p<0.01

Table 6.1. The cumulative effect of pro-environmental values on the number of soil-related GAPs adopted by producers. The p-value thresholds are indicated on the table.

Chemicals-related practices adoption – Cumulative values

	Dependent variable:			
	Chemicals-related practices Adoption - Cumulative values			
	Values	Education	Agronomist	Edu&Agro
	(1)	(2)	(3)	(4)
Intercept	**-0.106**	**1.177**	**1.397**	**1.116**
	p = 0.650	**p = 0.103**	**p = 0.022****	**p = 0.111**
Cumulative Values	-0.017	-0.092	-0.096	-0.092
	p = 0.910	p = 0.533	p = 0.522	p = 0.545
Area (100ha)		0.001	0.001	0.001
		p = 0.308	p = 0.237	p = 0.218
Age		-0.022	-0.027	-0.024
		p = 0.052*	p = 0.015**	p = 0.036**
Time Residence		-0.012	-0.010	-0.008
		p = 0.333	p = 0.420	p = 0.487
Biome		-0.242	-0.195	-0.184
		p = 0.488	p = 0.579	p = 0.601
Training		0.234	0.267	0.270
		p = 0.345	p = 0.286	p = 0.276
Education		0.045		0.201
		p = 0.859		p = 0.448
Agronomist			-0.392	-0.475
			p = 0.191	p = 0.133
Observations	99	99	99	99
Log Likelihood	-118.859	-110.181	-109.274	-108.987
Akaike Inf. Crit.	241.719	236.362	234.549	235.974
Note:				*p<0.1; **p<0.05; ***p<0.01

Table 6.m. The cumulative effect of pro-environmental values on the number of chemicals-related GAPs adopted by producers. The p-value thresholds are indicated on the table.

Conservation-related practices adoption – Cumulative values

	Dependent variable:			
	Conservation-related practices Adoption - Cumulative values			
	Values	Education	Agronomist	Edu&Agro
	(1)	(2)	(3)	(4)
Intercept	**-0.258**	**0.198**	**1.232**	**0.119**
	p = 0.313	**p = 0.796**	**p = 0.068***	**p = 0.874**
Cumulative Values	-0.063	-0.143	-0.134	-0.146
	p = 0.699	p = 0.393	p = 0.425	p = 0.392
Area (100ha)		0.0005	0.0003	0.001
		p = 0.581	p = 0.662	p = 0.532
Age		-0.016	-0.027	-0.016
		p = 0.171	p = 0.021**	p = 0.170
Time Residence		0.004	0.001	0.006
		p = 0.746	p = 0.951	p = 0.653
Biome		-0.906	-0.912	-0.880
		p = 0.056*	p = 0.055*	p = 0.065*
Training		-0.111	-0.104	-0.088
		p = 0.674	p = 0.699	p = 0.738
Education		0.664		0.818
		p = 0.022**		p = 0.008***
Agronomist			-0.099	-0.426
			p = 0.749	p = 0.183
Observations	99	99	99	99
Log Likelihood	-113.427	-104.539	-107.216	-103.604
Akaike Inf. Crit.	230.853	225.077	230.433	225.208

Note: *p<0.1; **p<0.05; ***p<0.01

Table 6.n. The cumulative effect of pro-environmental values on the number of conservation-related GAPs adopted by producers. The p-value thresholds are indicated on the table.

General and type-specific adoption of GAPs (sum)

	Dependent variable:			
	GAPs	Soil	Chemicals	Conservation
	(1)	(2)	(3)	(4)
Intercept	**0.881**	**-3.059**	**1.203**	**0.254**
	p = 0.022**	**p = 0.00003*****	**p = 0.094***	**p = 0.734**
Water	-0.156	-0.025	-0.222	-0.487
	p = 0.294	p = 0.931	p = 0.399	p = 0.090*
Biodiversity	-0.071	0.083	-0.066	-0.444
	p = 0.580	p = 0.720	p = 0.776	p = 0.086*
Climate	0.351	0.242	0.046	0.915
	p = 0.052*	p = 0.430	p = 0.900	p = 0.012**
Area (100ha)	0.001	0.0005	0.001	0.001
	p = 0.054*	p = 0.553	p = 0.195	p = 0.239
Age	-0.007	0.025	-0.025	-0.018
	p = 0.238	p = 0.020**	p = 0.032**	p = 0.118
Time Residence	0.009	0.029	-0.007	0.010
	p = 0.187	p = 0.043**	p = 0.550	p = 0.474
Biome	-0.167	0.419	-0.171	-0.991
	p = 0.371	p = 0.138	p = 0.631	p = 0.039**
Training	0.305	0.986	0.256	-0.146
	p = 0.026**	p = 0.0002***	p = 0.305	p = 0.589
Education	0.359	-0.111	0.205	1.066
	p = 0.017**	p = 0.688	p = 0.466	p = 0.001***
Agronomist	-0.354	0.408	-0.488	-0.750
	p = 0.049**	p = 0.222	p = 0.143	p = 0.036**
Observations	99	99	99	99
Log Likelihood	-180.434	-113.985	-108.797	-99.158
Akaike Inf. Crit.	382.867	249.970	239.594	220.316

Note: *p<0.1; **p<0.05; ***p<0.01

Table 6.o. Comparison of the effect of pro-environmental values on the general and type-specific number of GAPs adopted by producers. The p-value thresholds are indicated on the table.

General and type-specific adoption of GAPs (all DVs)

	Dependent variable:						
Regression type	*Poisson*	*Poisson*	*logistic*	*Poisson*	*logistic*	*Poisson*	*logistic*
Dependent var.	GAPs	Soil	Soil01	Chemicals	Chemicals01	Conservation	Conservation01
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Intercept	**0.88**	**-3.06**	**-4.92**	**1.20**	**4.16**	**0.25**	**0.35**
	p = 0.03**	**p = 0.0001*****	**p = 0.005*****	**p = 0.10***	**p = 0.02****	**p = 0.74**	**p = 0.83**
Water	-0.16	-0.02	0.36	-0.22	-0.57	-0.49	-0.83
	p = 0.30	p = 0.94	p = 0.53	p = 0.40	p = 0.36	p = 0.09*	p = 0.16
Biodiversity	-0.07	0.08	-0.05	-0.07	0.35	-0.44	-0.88
	p = 0.58	p = 0.72	p = 0.92	p = 0.78	p = 0.48	p = 0.09*	p = 0.09*
Climate	0.35	0.24	0.70	0.05	-0.03	0.92	1.61
	p = 0.06*	p = 0.43	p = 0.35	p = 0.90	p = 0.97	p = 0.02**	p = 0.04**
Area (100ha)	0.001	0.0005	0.003	0.001	0.003	0.001	0.002
	p = 0.06*	p = 0.56	p = 0.09*	p = 0.20	p = 0.15	p = 0.24	p = 0.34
Age	-0.01	0.03	0.05	-0.02	-0.07	-0.02	-0.02
	p = 0.24	p = 0.02**	p = 0.06*	p = 0.04**	p = 0.01***	p = 0.12	p = 0.46
Time Residence	0.01	0.03	0.03	-0.01	-0.01	0.01	0.03
	p = 0.19	p = 0.05**	p = 0.25	p = 0.55	p = 0.73	p = 0.48	p = 0.36
Biome	-0.17	0.42	1.21	-0.17	0.15	-0.99	-1.89
	p = 0.38	p = 0.14	p = 0.07*	p = 0.64	p = 0.82	p = 0.04**	p = 0.03**
Training	0.30	0.99	1.40	0.26	0.13	-0.15	-0.44
	p = 0.03**	p = 0.0002***	p = 0.02**	p = 0.31	p = 0.82	p = 0.59	p = 0.44
Education	0.36	-0.11	0.49	0.20	0.45	1.07	2.04
	p = 0.02**	p = 0.69	p = 0.42	p = 0.47	p = 0.47	p = 0.001***	p = 0.002***
Agronomist	-0.35	0.41	0.37	-0.49	-0.96	-0.75	-1.60
	p = 0.05**	p = 0.23	p = 0.59	p = 0.15	p = 0.20	p = 0.04**	p = 0.03**
Observations	99	99	99	99	99	99	99
Log Likelihood	-180.43	-113.98	-60.33	-108.80	-55.11	-99.16	-55.45
Akaike Inf. Crit.	382.87	249.97	142.67	239.59	132.22	220.32	132.90

Note: *p<0.1; **p<0.05; ***p<0.01

Table 6.p. Comparison of the effect of pro-environmental values on the general and type-specific number of GAPs adopted by producers, as well as on whether a producer adopts at least one type-specific GAP. The p-value thresholds are indicated on the table.

Changement de Politiques ou Changement de Valeurs ? L'évolution du Comportement Environnemental des Grands Producteurs de Soja du Mato Grosso au Brésil

Résumé : La production de *commodities* continue de s'étendre dans le monde. Historiquement, ces aires de production ont créé des opportunités économiques mais ont également eu des implications sociales et environnementales discutables. En 40 ans, l'État du Mato Grosso est devenu le principal producteur de soja du Brésil, représentant un quart de la production brésilienne et de 9% de la production mondiale, une expansion fulgurante vivement critiquée pour avoir causé des taux élevés de déforestation. Cette production est le résultat de petits exploitants agricoles qui ont émigré du sud du Brésil dans les années 1970 pour devenir aujourd'hui des grands producteurs de soja. Bien que les politiques environnementales adoptées dans les années 2000 aient réduit la déforestation, l'interaction entre ces politiques, les conditions de marché, la technologie agricole et l'évolution des valeurs des producteurs n'est pas claire. Quels sont les éléments constitutifs du comportement environnemental de ces producteurs et comment expliquer son changement ? Afin d'examiner cette évolution, nous avons choisi une approche multi-méthodes fondée sur une enquête de terrain comprenant 104 entretiens semi-structurés avec des producteurs, ainsi que des données quantitatives (changement d'utilisation des sols et analyse statistique). Bien que ce changement de comportement soit en partie lié aux conditions de marché et aux politiques environnementales, nous démontrons que l'identité techno-culturelle et les valeurs pro-environnementales de ces producteurs ont contribué de manière significative à ce changement. Cette thèse contient des enseignements précieux pour comprendre les mécanismes complexes susceptibles de limiter l'impact environnemental des futures frontières agricoles.

Mots-clés : politiques environnementales, valeurs, soja, grands producteurs, Brésil, Mato Grosso

Policy Change or Values Change? The Evolution of the Environmental Behavior of Large-Scale Soybean Producers in Mato Grosso, Brazil

Abstract: Commodity production keeps expanding around the world. Past areas of commodity production have provided economic opportunities, but mixed social and environmental outcomes. In 40 years, Mato Grosso state has turned into the largest Brazilian soybean producer, representing a quarter of the country's and 9% of the world's production. Criticism of deforestation outcomes abounded. Much of that production was the result of smallholder farmers who migrated from southern Brazil in the 1970s and turned today into large-scale soybean producers. While environmental policies since the mid-2000s contributed to deforestation reduction in the region, the interplay between these policies, market conditions, technology and changing farmers' values is unclear. What constitutes the environmental behavior of these producers and what explains that it evolves over time? To examine this evolution, I used a multi-methods approach based on extensive field research, 104 semi-structured interviews with producers, and quantitative data (land-use change and statistical analysis). Although the behavioral change of large-scale soybean producers has partly to do with market conditions and environmental policies, I demonstrate that their evolution in that regard is the result of a particular techno-cultural identity and pro-environmental values developed over time. This dissertation holds valuable lessons for understanding the complex mechanisms that could limit the environmental impact of future commodity frontiers.

Keywords: environmental policy, values, soybean, large-scale producers, Brazil, Mato Grosso

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