# BRAZIL FARMLAND PRICE VOLATILITY IN DISTINCT PRODUCTION REGIONS

by


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**ABSTRACT**

Land is a fundamental input in agricultural production and the factors affecting land prices are an important topic in agricultural economics research. The farmland market has several unique characteristics. Land price volatility can be a source of problems for farmers and investors, especially in periods of falling prices in locations far from markets where the impact of land price reductions is higher than in other locations.

This study analyzes land price volatility in different geographical regions of Brazil. The hypothesis is that variation in land price increases with the distance to the market, indicating that land price changes will be more pronounced in areas far from markets and the effects of price cycles in land markets will increase as distance from the market increases.

The results obtained in this research support the hypothesis that areas far from end markets are exposed to greater changes in land prices and those same areas are more susceptible to price cycles. The effect on price volatility was also stronger in periods of land price declines. These regions have greater incentives for expansion and investment in periods of land price increase and greater risks of disinvestment and failure in periods of land price contraction.

It is difficult to predict when a cycle of expansion or crisis will start or finish, but the present study helps to understand the effects of increases or decreases in land prices when such an event occurs.

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# CHAPTER I: INTRODUCTION

The rise in income and a growing middle class in developing countries is associated with an increase in food and energy demand, and is forcing the development of new farmland around the world to support increased consumption. The expansion is occurring in agricultural producing countries like Brazil, where significant investments in agricultural land has occurred by farmers and investors in the last decades.

In Brazil, the investments in land are mostly related to soybean, corn, cotton, coffee, reforestation and sugarcane production resulting in an increase of farmland values over time and attracting investors' attention in this growing agricultural market.

Brazil is a prominent producer in the world agribusiness sector, being a major producer and exporter of agricultural commodities. The Brazilian ranking in production and exports of agricultural commodities is reported in table 1.1.

**Table 1.1: Brazil in the world ranking of agricultural commodities**

| Product | Production | Exports |
|---|---|---|
| Sugar | 1st | 1st |
| Coffee | 1st | 1st |
| Orange Juice | 1st | 1st |
| Beef | 1st | 1st |
| Ethanol* | 2nd | 1st |
| Soybean Complex | 2nd | 1st |
| Poultry | 2nd | 1st |
| Corn | 3rd | 1st |
| Pork | 3rd | 3rd |
| Cotton | 5th | 4th |

**Source: (USDA, Foreign Agricultural Service 2014);** (RFA 2013)**;**
*** 2012 for Ethanol**

Brazil produced 186.8 million tons of grain and oilseeds in 2012/13 crop year, with the soybean complex being the most important in terms of total area, production, exports and revenue generation. In 2012/13 Brazil's soybean production reached 81.5 million metric tons, representing 42.9% of total grains and oilseeds production (CONAB 2014).

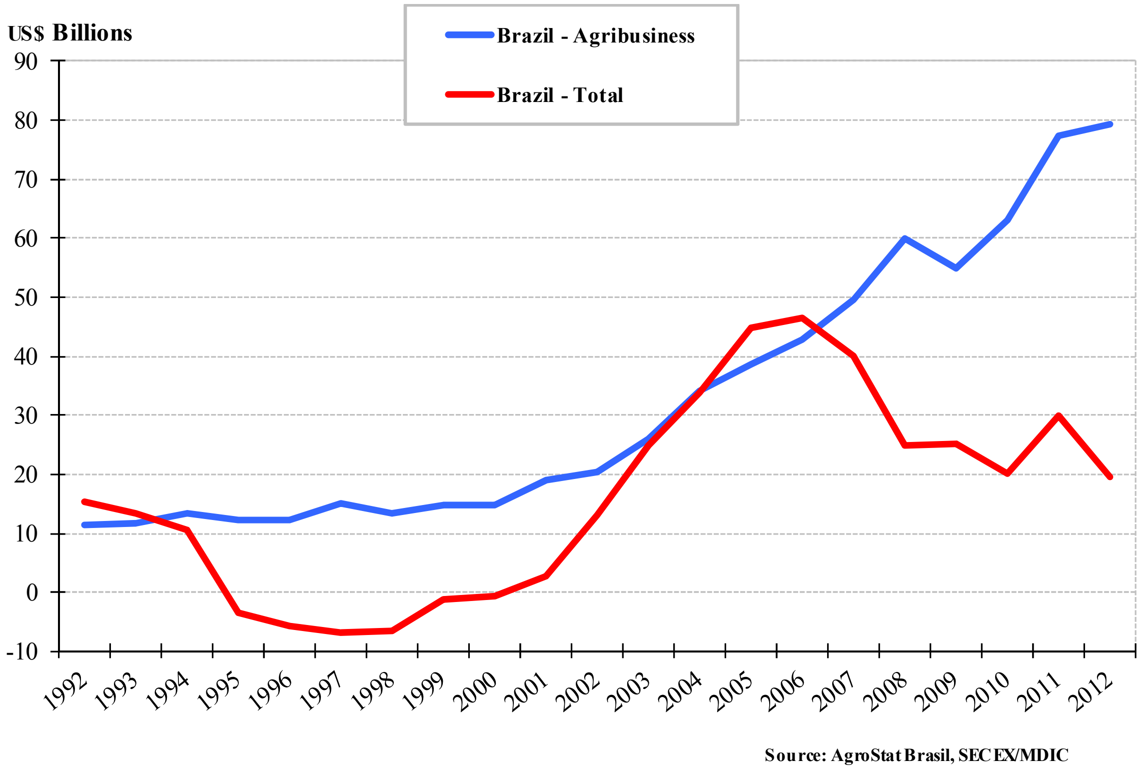
Brazil exported 42.8 million metric tons of soybean in bulk grain, 13.3 million tons of soymeal and 1.2 million tons of soybean oil, representing 30.8 billion U.S. dollars in income in 2013 (SECEX 2014).

Corn is the second most important grain in terms of production. In 2012/13, the 81 million metric tons produced represented 42.7% of the total output. In 2013, Brazil exported 25.3 million tons of corn (CONAB 2014).

Brazil is the biggest producer and exporter of sugar and ethanol. In the 2012/13crop year, 589 million metric tons of sugar cane were produced (CONAB 2014), and 21.5 million metric tons of sugar and 1.2 million metric tons of ethanol were exported (SECEX 2014).

Brazil has increasingly used agribusiness as a means of integration into the world's economy. Exports of Brazilian agricultural products play an important role in the supply of foreign exchange and domestic incomes for Brazil. In the 20 years from 1992 until 2012, Brazilian agribusiness exports grew 563% from 14.45 billion U.S. dollars in 1992 to 95.8 billion U.S. dollars in 2012. In 2012, agribusiness exports accounted for 39.5% of total Brazilian exports and had a surplus of 79.5 billion U.S. dollars. The agribusiness positive trade balance helped Brazil maintain a positive trade surplus of 19.44 billion U.S. dollars (AGROSTAT BRASIL 2013), Figure 1.1.

**Figure 1.1: Brazilian Net Agribusiness and Total Trade Balance from 1992 to 2012 (US$ Billion)**

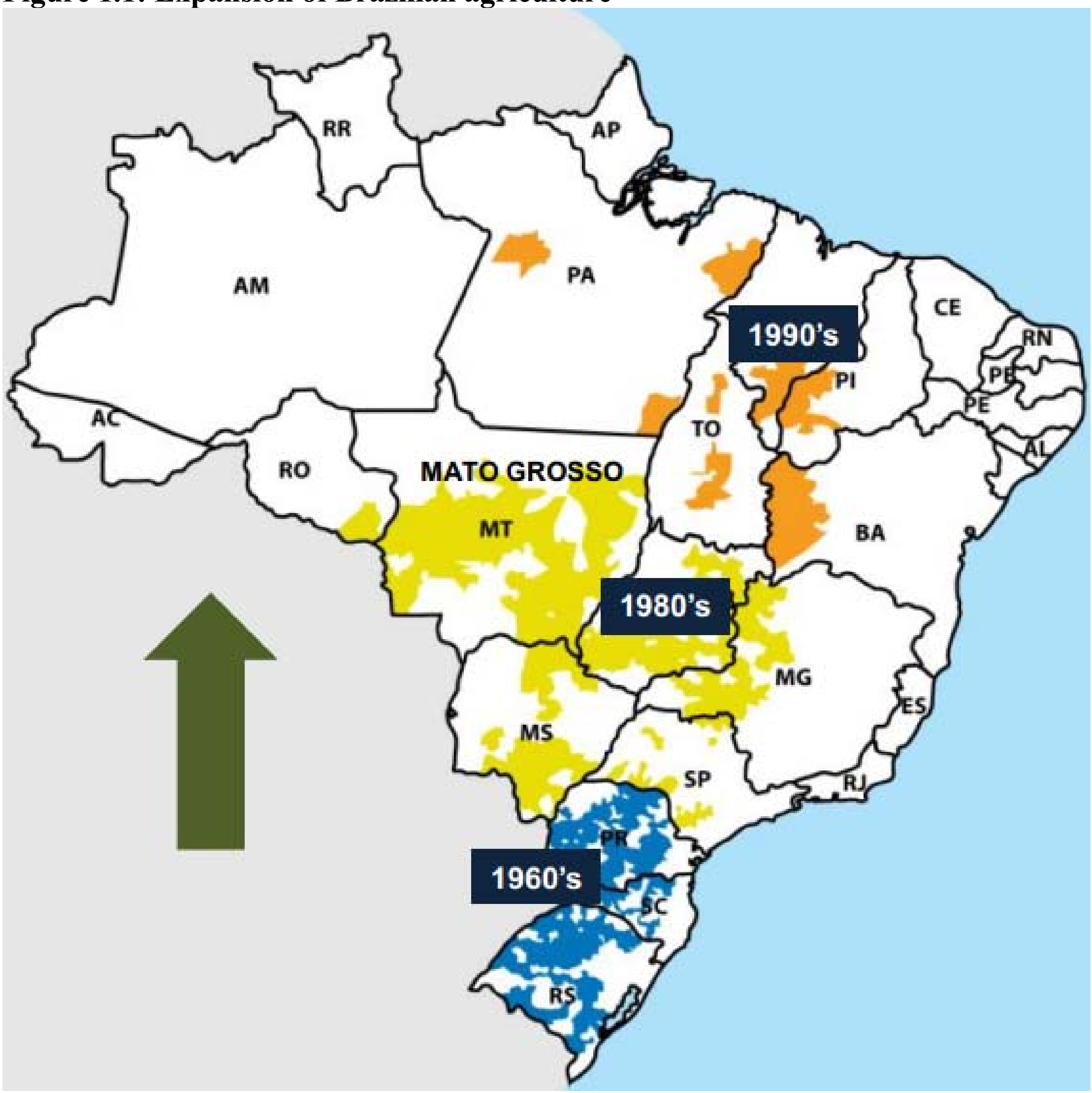



## 1.1 Expansion of mechanized agriculture in Brazil

Mechanized farming of grains has been a factor in Brazil since 1960, boosted by a wheat subsidy policy aimed at grain self-sufficiency. In the years following, wheat, corn and soybeans became economically important in Brazil. In 1970, more than 80% of the volume produced was concentrated in three states of Southern Brazil (Rio Grande do Sul, Santa Catarina and Paraná). In the following two decades (1980s and 1990s) soybean varieties better adapted to tropical regions induced an explosive growth of production in the states of Center West Brazil. In 1980, the Center West of Brazil was 20% of the soybean area. In 1990, the area exceeded 40% and in 2003, it was close to 60% with expectation to occupy more space with each new harvest.

This transformation resulted in the State of Mato Grosso moving from a marginal producer to a national leader in agricultural production, with good prospects for expanding this position (EMBRAPA 2004). The area of soybean production is illustrated in Figure 1.2.

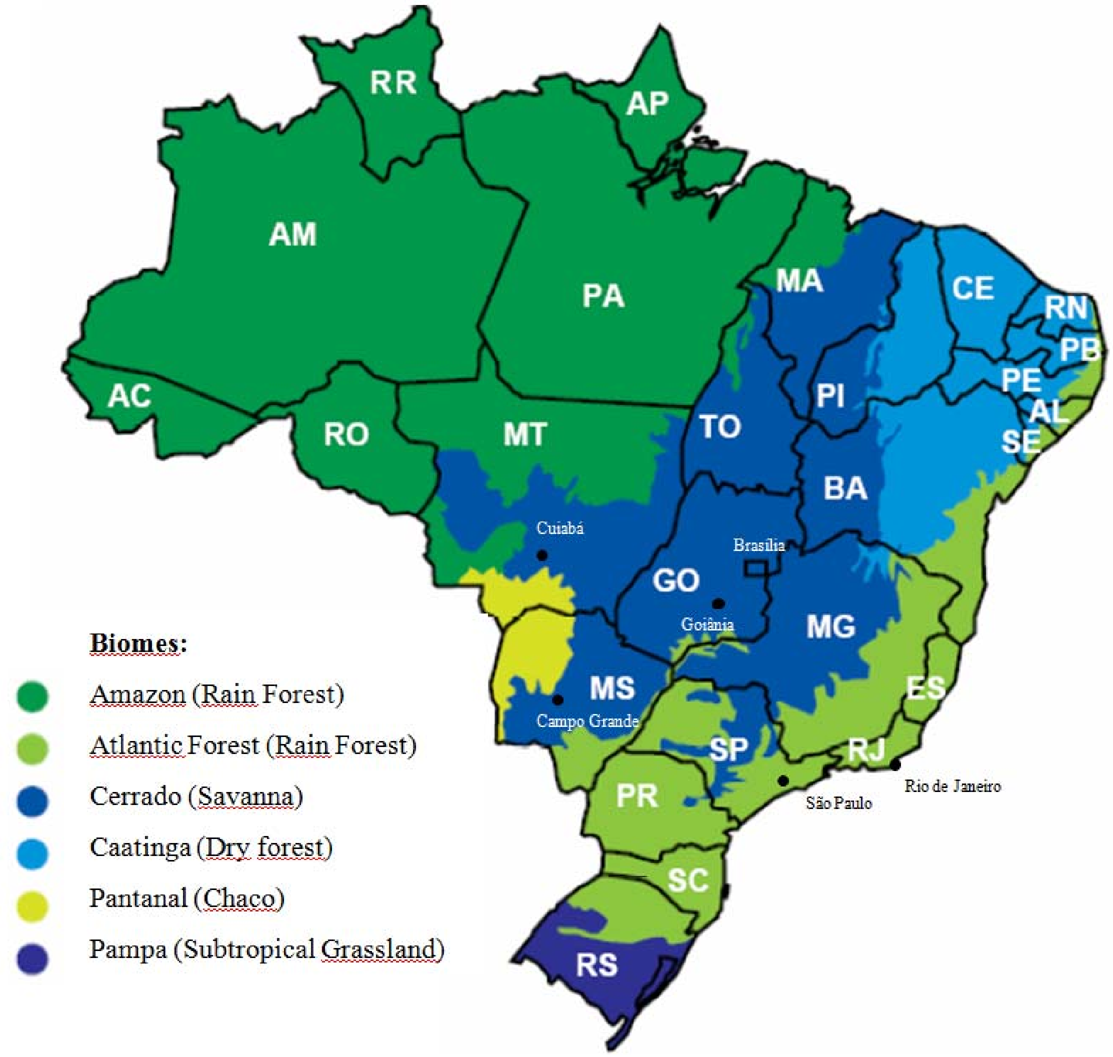
**Figure 1.1: Expansion of Brazilian agriculture**




**Source:** (EMBRAPA 2004)**.**

The region of the Brazilian Savanna called 'Cerrado' is delimited on the map in Figure 1.3. This region is considered to be the new frontier of agriculture in Brazil, where the topography is flat land in plateaus that is highly favorable for mechanized agriculture.

**Figure 1.2: Pre-agricultural Brazilian biomes**




**Source:** (GEOCURENTS 2014)

The main reasons for the success of agriculture in the Cerrado region is the development of a successful technological package with emphasis on the new varieties adapted to the conditions of low latitudes. The topography is highly favorable to mechanization and the abundant and low cost of land in the region adds economic value. The rainfall in the region is also highly favorable for summer crops, in contrast with the frequent dry spells that occur in the southern region, notably in Rio Grande do Sul state (EMBRAPA 2004).

Figure 1.4 illustrates the original vegetation of the Cerrado. Figure 1.5 illustrates the area after transformation to crops.

**Figure 1.3: Brazilian Cerrado Original Vegetation**

**Figure 1.5: Brazilian Cerrado Developed Farmland**

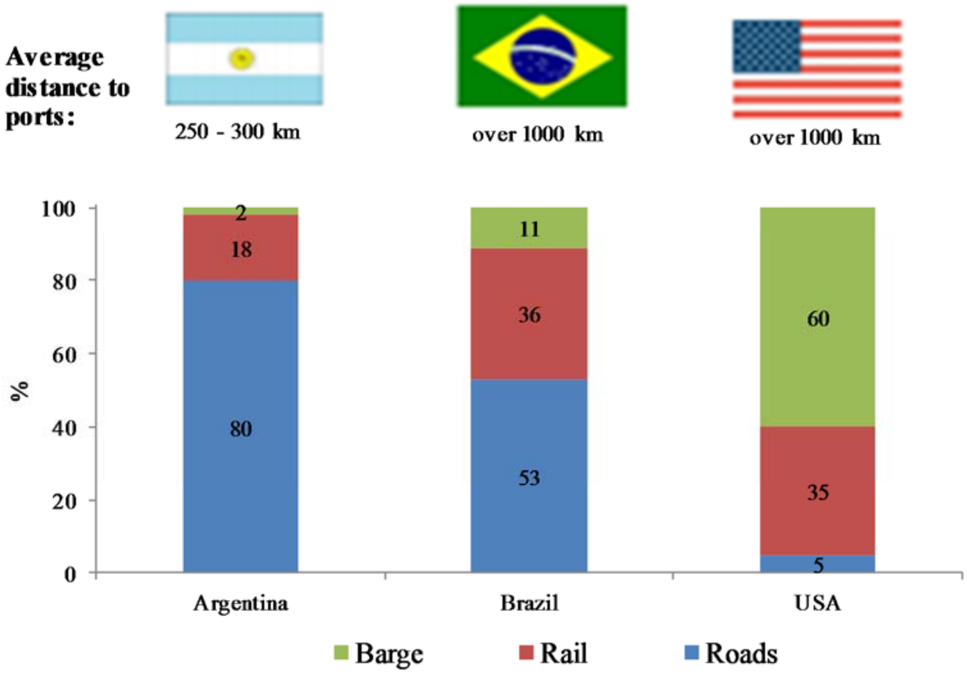

### 1.2 Distance to the market and logistics constraints

Despite the rapid growth of production in the central regions of Brazil, the transport infrastructure, which is important to access domestic and international markets, has not developed at the same pace. Brazilian soybean production compared to U.S. soybean production is competitive at a farm level, but this situation is reversed after harvest. The production loses its competitiveness due to deficiencies in the logistics that affect the transport costs for domestic and foreign markets (Vasconcelos 2008).

This problem of logistics is further exacerbated by the expansion of agriculture in new frontier regions being more than 1,000 km (621.5 miles) from ports and important domestic markets. Unlike Brazil, U.S. and Argentinean logistic costs are much lower for their agricultural production. In a survey of Brazilian agribusiness executives, respondents cited the logistics infrastructure as the major problem for agribusiness (EXAME 2008).

The Brazilian transportation system is heavily based on truck transportation which represents 53% of the national transport mix while the railroads and waterways represent 36% and 11% respectively (ANEC 2012). Making a comparison with the U.S. that has similar continental dimensions and distance between the production and consumption regions, it is possible to examine the differences between the infrastructure in the two countries. In the U.S., the predominant mode for grain exports is via waterways representing about 60% of the national transport mix, 35% by railway and only 5% by truck transportation (ANEC 2012). Despite the logistics system in Argentina being based on truck transportation, the production regions are located in a radius of about 300 km (186.5 miles) from ports. The comparative grain logistics matrix of Brazil, the U.S and Argentina is illustrated in Figure 1.6.

**Figure 1.6: Distances and Comparative grain Logistics Matrix for Brazil, the U.S. and Argentina**

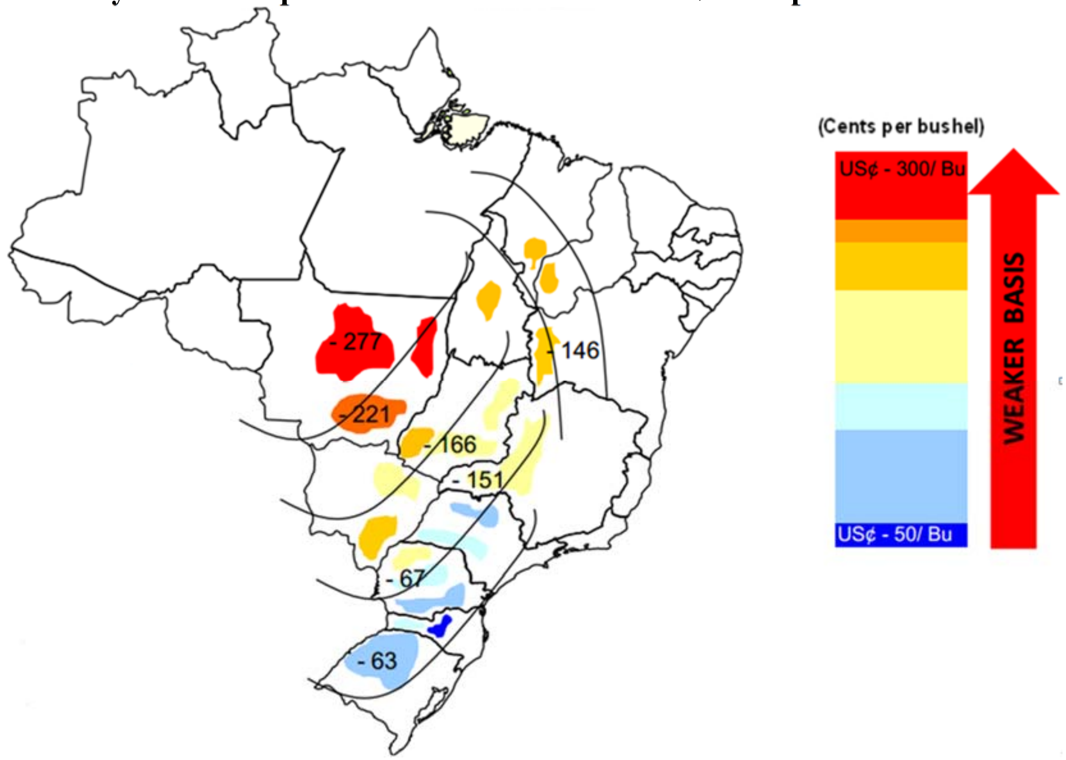



Source: ANEC 2012

The Brazilian internal grain transport and export occurs at a very high cost compared to its major competitors. According to SIFRECA (2012), the cost of soybean transport from the interior of Brazil to the ports costs on average US$ 62 per ton. In the most distant regions such as the agricultural frontier (northern Mato Grosso state), the cost of transport can reach US$ 110 per ton, while the U.S. transports soybeans at a cost of US$ 36 per ton (USDA 2011). This shows the deficiency of Brazil's logistics infrastructure.

The State of Mato Grosso which is part of the Brazilian agricultural frontier has the highest logistic costs in the country. The transportation to the nearest port is expensive due to the distance, in some cases above 2000 kilometers (1243 miles) with transportation by truck (APROSOJA 2011). Figure 1.7 shows the cost to transport 1 bushel of grain from the production region to the port. The price basis increases significantly as the distance to the ports (market) increases, being close to US$/bu 3.00 in the state of Mato Grosso.

**Figure 1.7: Soybean Transportation Costs in Brazil in US$ cents per bushel**



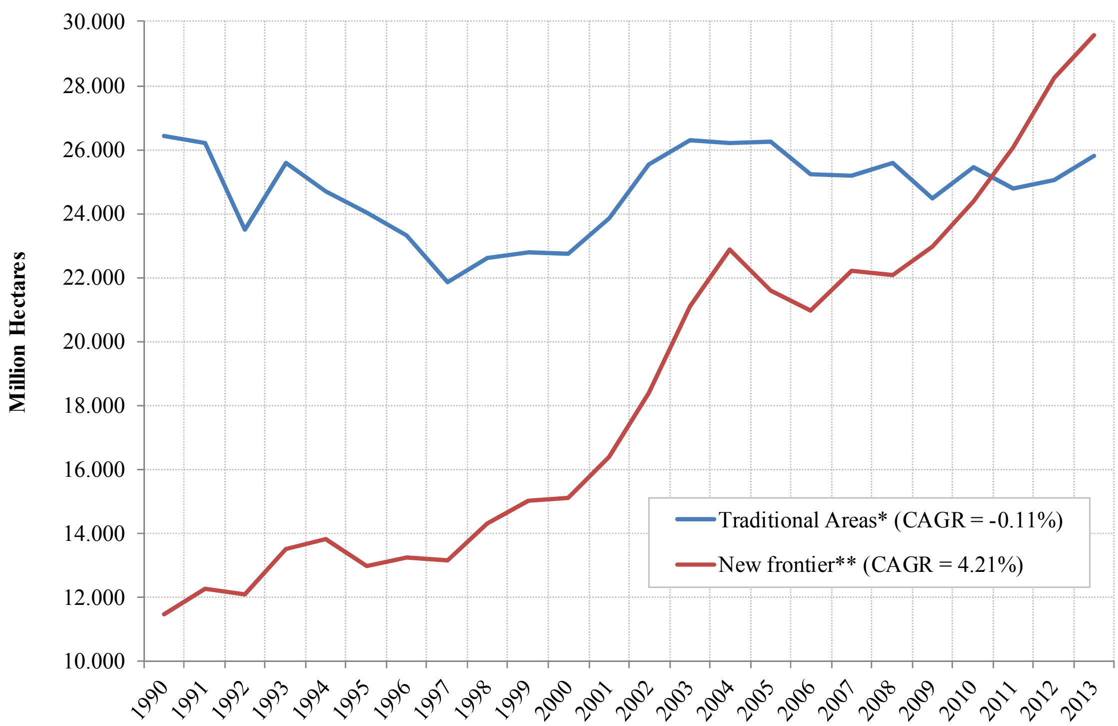

Source: (APROSOJA 2011).

### 1.3 Brazil Land Availability and Land Prices

Despite the poor logistic conditions, Brazil's recent growth in the agribusiness sector is based on an abundant land supply and relative low prices especially in the northern regions of the country. In the last decades, Brazil has experienced one of the most rapid expansions in new farmland development in the world, transforming the Cerrado and pasture land into new farmland.

Figure 1.8 illustrates the development of agricultural land in Brazil. Total grains and oilseed area has increased since 1990. Traditional regions (South, Southeast and parts of Northeast region) have had negative growth while new frontiers of development (States of Center West, North and parts of Northeast regions) have experienced an impressive compounded annual growth rate (CAGR) of 4.1% over the last 23 years.

**Figure 1.8: Brazil Land Used in Agriculture in Traditional Areas and in New Frontiers**




Source: (CONAB 2014); *Traditional regions (South, Southeast and parts of Northeast). New frontiers: (Center West, North and parts of Northeast).

Despite the recent increase in land use, there is still an abundant supply of land in Brazil. According Agrostat Brasil (2013), Brazil is using 72 million hectares in agriculture

(8.5% of the total territory) and has the potential to develop 71 million hectares more, almost double the area, not considering the Amazon forest (Table 1.2).

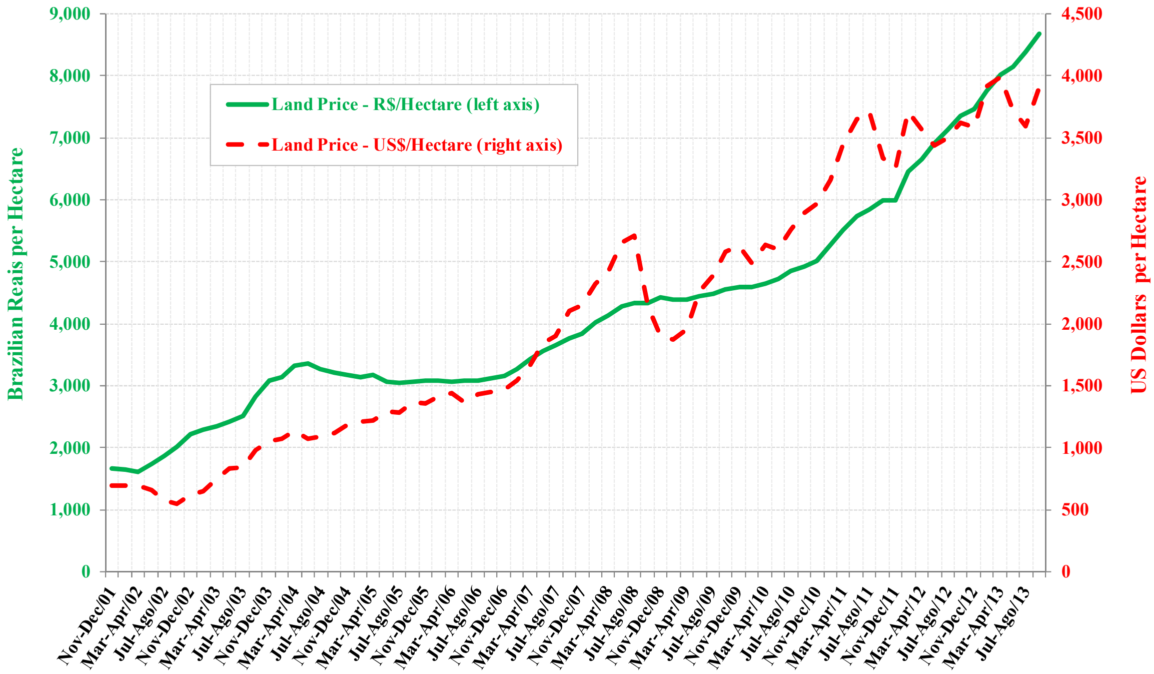
**Table 1.1: Land use in Brazil (current and potential)**

| | Million Hectares | % of Total Area |
|---|---|---|
| Amazon Forest | 360 | 42.3% |
| Pasture | 172 | 20.2% |
| Agriculture - Annual Crops | 55 | 6.5% |
| Agriculture - Permanent Crops | 17 | 2.0% |
| Planted Forests | 5 | 0.6% |
| Other Uses | 171 | 20.1% |
| **Available Land for Agriculture** | **71** | **8.3%** |
| **Total** | **851** | **100.0%** |

Source: (AGROSTAT BRASIL 2013)

Land price increases in Brazil have been consistent with a few exceptions. Figure 1.9 shows the average land price in Brazil surveyed by Informa Economics FNP (2014) expressed in Brazilian Reais (R$) and U.S. Dollars (US$) per hectare.

**Figure 1.9: Average land price in Brazil**




Source: Informa FNP

One issue for farmers and investors is to understand the factors that influence land prices and their effect on land as an investment opportunity. This is especially important if land is considered to be a safe investment and its returns and risks compared with other investment alternatives.

Farmers and investors continue to buy land in different regions in Brazil. For many investors, farmland is viewed as a long term investment where farming the land permits short term cash dividends and land price appreciation accumulates to provide long term returns with low volatility and risk.

The agricultural land market has several unique characteristics. The market has low liquidity and often a key factor in moving the market price is the returns from agricultural production. However, the land market can also be influenced by factors like yield potential, soil type, rainfall pattern and distance from markets.

These factors are not fully comprehended in Brazil and little research has been done to understand the behavior of land prices and its impact when considering distinct production regions.

The majority of new land transactions are conducted in the new development regions (new frontiers) usually far from consumer markets (domestic markets and ports). The goal is to understand and compare the dynamics of land prices in these regions and compare them with more traditional regions closer to consumption regions and ports.

Because the issue is very complex, this research analyzes land price volatility in different geographical regions of the country by adapting the research carried out by Bernirschka and Binkley (1994) to Brazilian land market conditions. They used land prices from the U.S. and tested and confirmed the historical evidence and theory that land price variation increases with the distance to the market, and price changes are more pronounced in areas far from markets, and the effects of a boom and bust in land price increases as distance from the market increases.

The objective of this research is to examine the land price volatility in different regions of Brazil and test the hypothesis that changes in land prices are relatively greater in production regions far from the markets. Additionally the importance of soybean prices will be tested as an indicator of land price behavior in Brazil. Sub-objectives are to try to identify the main factors that have impact on land price volatility in different regions and create a model to predict future land prices in different regions of the country.

Chapter 2 will review the previous research on land price volatility. Chapter 3 will discuss the theory and the conceptual model. Chapter 4 will present the methods. Chapter 5 will present the results and Chapter 6 the study's conclusions.

# CHAPTER II: LITERATURE REVIEW

Land is the fundamental input in agricultural production and the farmland market has several unique characteristics that are an important topic in agricultural economics research. This study analyzes the land price volatility in different geographical regions of Brazil. The previous research related to this topic is summarized in this chapter.

Farmland price behavior studies date from the $19^{th}$ century when Ricardo (1815) introduced the concept of marginal products where the most fertile lands are always used first, and the less fertile land is used later. Land fertility is the primary factor behind differences in land rent and prices. According to the Ricardian theory for land rent, when the less fertile land is cultivated to feed a larger population, the cost of production is equal to the market price for grain, resulting in no surplus or profit. The rent of the most fertile lands depends on the difference in the quality of the marginal land and the quality of the land is then capitalized into land rents and values.

Other factors affect land prices. The classical economist Von Thunen (1826) added the concept of spatial variation in land values. The model described by Von Thunen (1826) in the book “The Isolated State” included the distance to the market as a factor affecting land values. The distance to the market and ultimately the transportation cost determines land rent, assuming that land quality and unitary cost of production are constant.

In essence, the Von Thunen model is similar to the Ricardian theory of marginal products with one difference. Instead of land quality, transportation costs define land rent and value as the cost of production plus transportation to the market from the most distant production regions is equal to the market price for production. Land rent decreases as the distance to the market increases.

Land is a critical asset in the agricultural sector and increasing land prices have attracted the attention of researchers and market participants, raising questions about what factors have the greatest impact on farmland values (Gloy, et al. 2011).

Historically, farmland price cycles have caused severe impact on rural economies (Featherstone and Baker 1987). In the U.S., where farmland price changes overtime have been studied, researchers have developed distinct models and concepts to better understand the behavior of land markets.

Fontnouvelle and Lence (2002), argued that farmland price cycles are related to the financial health of the agriculture industry and historically have raised concerns in the sector related to the banking system.

"The propensity for periodic long-term swings in the value of farm assets has been an important, almost inherent, characteristic of the agricultural sector and the effects of these extended over several decades, and each shaped the fortunes of a generation of farmers, landlords, suppliers, and lenders" (Featherstone and Baker, 1987, p. 532).

In the simplest economic approach, land price is the net present value (NPV) of future income (land rent). But according to the literature, there are many other factors affecting farmland prices. Pyykkönen (2006) divided the factors into two subcategories: internal and external factors. He defined internal factors as the quality of land, productivity of land, market income, investment support, fragmentation of the land, structural change and concentration of production; and the external factors include the infrastructure, interest rate, taxation, non-farm demand for the land and restrictions on land use or purchase affecting farmland prices. According to Pyykkönen (2006), characteristics that have a direct impact on cultivation returns like quality (soil type, fertility, irrigation etc.), lot size, latitude or altitude and the length of the growing period, directly reflects Ricardian rent.

There are many factors affecting land prices. Roka and Palmquist (1997) analyzed the farmland prices of a large farm survey in the U.S. Corn Belt. They tested land prices as a function of the size of the farm, the land use, farm ownership, proportion of primary land, the proportion of erodible land, population density, corn yield and selling experience in recent years. They analyzed four models, and the best model explained about 34% of the overall land value variability, suggesting that important explanatory variables were omitted.

Featherstone and Baker (1987) studied the propensity for bubbles in land prices using vector autoregression to study the dynamic response of real farm asset values to changes in net returns and interest rates. They found that a shock in real asset values, real returns to assets, or real interest rates leads to a process in which real asset values overreact. "In the initial period, a reaction to a shock immediately occurs followed by a continued build-up in the asset value for up to six years until finally the effect of the one-time, transitory shock begins to die out. The results suggest a market with a propensity for bubbles" (Featherstone and Baker, 1987, p. 532).

The effect of risk on farmland values and returns was analyzed by Katchova, Sherrick and Barry (2002) using a capitalization model. The results showed differences in production risk affected farmland prices indicating that farmland that carries greater risk in income generation has a lower value. Rental rates are correspondingly lower when the income stream carries greater risk.

Benirschka and Binkley (1994) tested the hypothesis that areas located relatively far from markets experience relatively greater changes in land prices. They studied the rise in land prices in the U.S. Corn Belt from 1969 to 1982 and their subsequent decline from 1982 to 1987. "As long as changes in land prices are at least in part a response to changes in rents and, ultimately, returns (and the evidence is that they are), land price changes will be more pronounced in producing areas far from markets, and the ill effects of boom and bust in land markets will tend to worsen as distance to market increases." and "if boom and bust cycles are a response to swings in farm profits and thus ultimately in prices, the severity of cycles would be a function of the extent of price changes. Then geographic differences in the magnitude of price changes would cause geographic differences in the severity of cycles. Under most conditions, differences in the degree of price movements will exist across regions. Specifically, prices will increase and decrease relatively more with increasing distance to market" (Benirschka and Binkley 1994, p.186).

The results of Benirschka and Binkley's research support the theory that the price of less favorably located farmland increased relatively more during the 1969 to 1982 period, and the collapse was also greater in those same areas from 1982 to 1987. The authors concluded that a land price increase gives stronger incentives to expansion in areas far from the market and a land price decrease causes greater contraction, disinvestment and failure in such areas. Producers in areas relatively far from markets should be especially cautious when making investment decisions or should adopt more flexible production methods because these areas can be especially affected by land price cycles.

In Brazil, land markets have become very dynamic in recent years due to the growth of agribusiness, attracting the interest of investors due to the large amount of land available for agricultural expansion. Brazil is one of the top countries with the potential to expand production.

There are many less developed areas of the country known as the agricultural frontiers where land prices are lower compared to traditional areas. These areas attract the attention of investors because by occupying marginal areas before investments in infrastructure and transportation have occurred, there is a greater future appreciation potential (Rezende 2002).

In a recent research study in Brazil, Ferro (2012) analyzed the impact of characteristics on the price of agricultural land in three different regions: the agricultural frontier in the south of Maranhão, south of Piauí, eastern region of Tocantins and west of Bahia; the transition area in the Central-Western region of Brazil, which already represents a major soybean producing region; and the more traditional and developed agricultural regions, such as the South of Brazil. Ferro found that in less occupied regions an increase in the demand may lead to a negative impact on its prices because of the higher elasticity of the land supply and the possibility of converting raw lands and pastures into agricultural areas. This occurs because land conversion shifts the supply curve to the right which may negatively impact the land price. In the developed areas the relationship is positive, since land supply is almost inelastic. Ferro (2012) also observed that speculation was an important factor in the agricultural frontier region, different from that observed in other regions, highlighting the strong interest of investor groups interested in the potential of land appreciation in that region.

Rezende (2002) analyzed the land market in the Cerrado region in Brazil and estimated different pricing models: first, second and virgin land. The author concludes that there is a trend of continued expansion of agriculture toward the virgin lands, instead of intensifying the use of areas already occupied by the conversion of pastures into cropland. According to the author, it is not plausible to consider only factors on the demand side where the implicit assumption is that the stock of land is constant. This is inappropriate for a country like Brazil.

This previous research provides a view of what researchers have studied to better understand land market behavior. According to the literature, the land market has several unique characteristics and there are many factors affecting land prices resulting in different methods and prediction models. This study will focus on land price behavior across space, different from the usual approach that studies land price behavior through time.

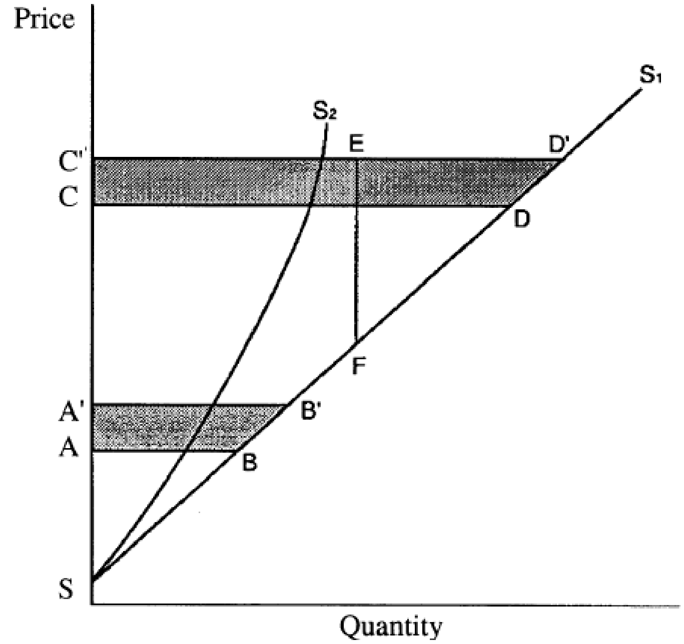
# CHAPTER III: THEORY AND CONCEPTUAL MODEL

Benirschka and Binkley (1994) expanded Ricardo's and Von Thunen's rent theory by studying land price volatility in geographically dispersed markets. Their model relates the changes (volatility) in land values with distance to market. In the model, changes in agricultural land prices are relatively greater in regions more distant from markets.

Assuming unchanged transport costs, the price variation of a single commodity e.g. soybean production, is not the same when considering different distances to the market. The impact of distance to the market for a single commodity results in lower prices as the transportation cost (distance to the market) increases. When a price change of the commodity occurs, the percentage price change is greater as the distance to the market increases. Output price changes will have a corresponding effect on rents that will be capitalized into land prices. This results in greater percentage increases in land price in remote producing areas (Benirschka and Binkley 1994).

In agriculture, higher output prices are a major factor that induces agricultural production expansion. The effects of production expansion in distant geographical regions can be verified in a graph of farm supply as illustrated in Figure 3.1. In the graph, supply is the linear segment $SS_{1.}$ The more favorably located farm 1, receives farm gate price C and produces at D, earning rent CDS. Farm 2, farther from the market, receives a lower farm gate price at A, produces at B, and earns a smaller rent of ABS. As output market price increases, there is an increase in rents represented in the shaded areas of the graph. The percentage increase is greater for farm 2 (triangle SA'B') than for farm l (triangle SC'D') (Benirschka and Binkley 1994).

**Figure 3.1: Farm-Level Supply** (Benirschka and Binkley 1994)




When higher output prices persist over time, higher rents are capitalized into land values and the percentage increase in land values is larger in less favorable locations. "If prices in a spatial market rise, as long as transport costs do not change, the relative importance of space declines, and in a new equilibrium differences in output across farms will be smaller. Therefore, relatively more production than previously will occur further from markets. In order to bring this about, profits, rents, and land values must rise relatively more in those areas" (Benirschka and Binkley 1994, p. 188).

The current study extends the research done by Bernirschka and Binkley (1994) in the U.S., adapted to Brazilian land market conditions. Similar to the original work, the explanatory variable of primary interest is the distance to markets. Additional variables are used to capture effects due to differences in land quality.

The basic equation considering the distance to the market for the model will be:

$$VC = \alpha + \beta D + \varepsilon \; ; \qquad (3.1)$$

where VC is the percentage change in land price over a given period, D is distance to market, and ε is the error.

## CHAPTER IV: METHODS

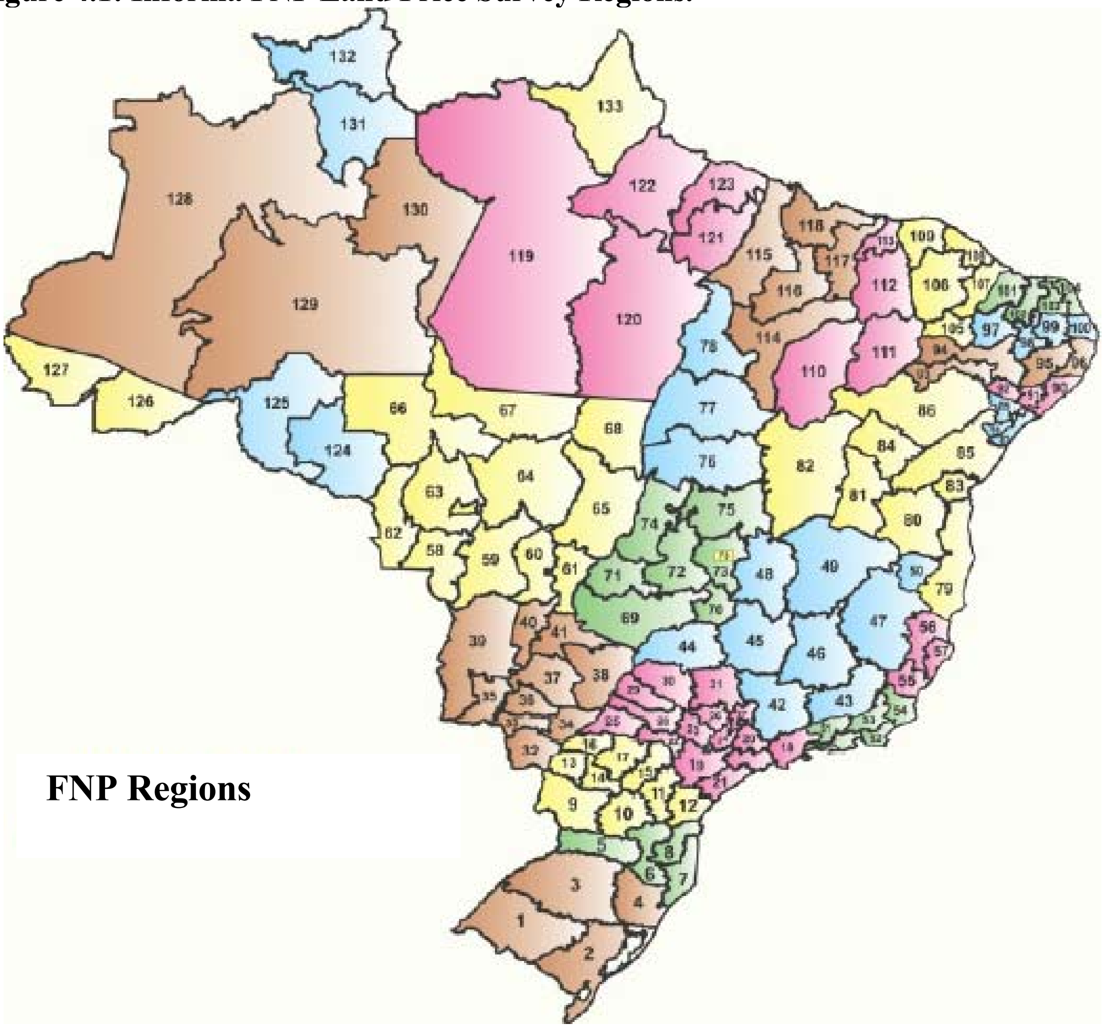
This chapter will present the methods used in this research. This study was conducted using prices of farmland in Brazil in distinct geographical regions in two different time periods. The first period of time studied was characterized by land price decreases and the second time period reflected land price increases. The information needed to estimate the model was land prices, soybean prices, soybean yield, land characteristics and the geographic location.

### 4.1 Data and Variables

#### *4.1.1 Land Price*

The main source of information (land price) comes from the systematic price survey of land prices in Brazil conducted by Informa Economics-FNP company. Land prices have been surveyed since 2001 and are measured every 2 months and expressed in Brazilian Reais per Hectare for 133 different and homogeneous regions in Brazil (Figure 4.1). Each of the regions is surveyed according to the basic characteristics such as soil type, use and climate. Other more specific characteristics of land price formation are surveyed in each region including the intensity level of the agricultural and livestock exploration, possibility of mechanization, topography, current or previous vegetation and average rainfall.

**Figure 4.1: Informa FNP Land Price Survey Regions.**




**Source: Informa Economics FNP**

High quality farmland from distinct geographic production regions in Brazil were selected to estimate the model. From the entire database, only regions that have substantial grain and oilseeds production, particularly soybean production, are included. In total, 52 of the 133 regions were selected (Table 4.1).

Two distinct periods were selected to study the land price behavior, one period of a land price increase and the other a period of price decrease (Figure 4.2). The first period selected was from June 2004 to June 2005, and was characterized by a land price reduction.

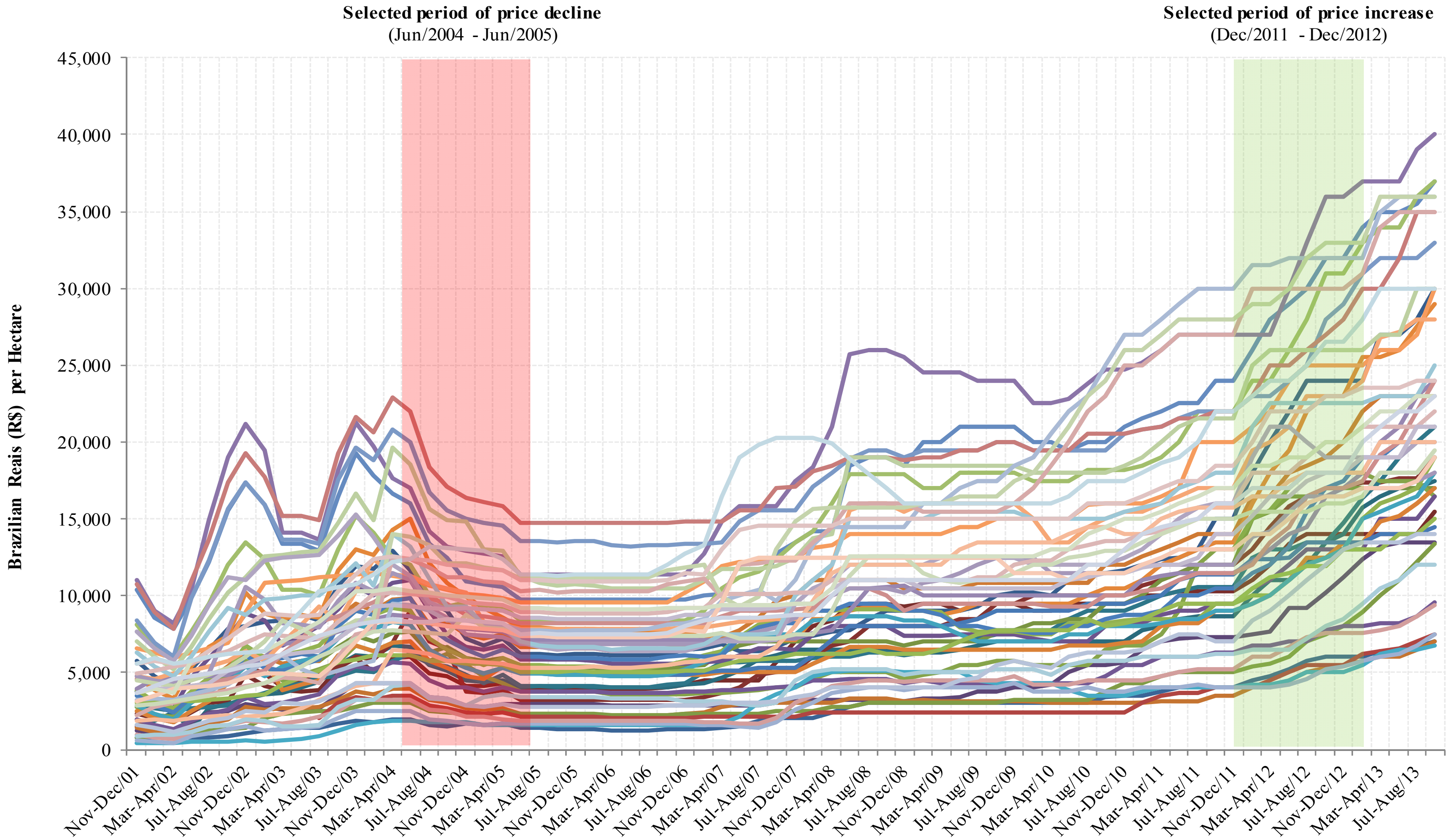
The second selected period from December 2011 to December 2012, was characterized by rising prices.

## Table 4.1: Selected Locations and Land Prices: Main Soybean, Corn and Cotton Production Regions in Brazil

| State | Region/City | Characteristhiscs | Period of Land Price Reduction (Jun/2004 - Jun/2005) | | Period of Land Price Increase (Dec/2011 - Dec/2012) | |
|---|---|---|---|---|---|---|
| | | | Land Price Avrg (R$/hectare) | Land Price Change in the Period (%) | Land Price (R$/hectare) | Land Price Change in the Period (%) |
| RIO GRANDE DO SUL | Passo Fundo | Farmland of high yield potential (Passo Fundo/Erechim) | 14,447 | -38.9% | 25,214 | 20.9% |
| RIO GRANDE DO SUL | Passo Fundo | Farmland of high yield potential (Santa Rosa/Três Passos) | 8,849 | -38.9% | 19,286 | 18.8% |
| RIO GRANDE DO SUL | Passo Fundo | Farmland of high yield potential (Santo Ângelo/Cruz Alta/Palmeira das Missões) | 9,456 | -46.4% | 21,643 | 25.0% |
| SANTA CATARINA | Chapecó | Farmland of high yield potential (Caçador) | 5,812 | -17.3% | 17,171 | 14.6% |
| SANTA CATARINA | Chapecó | Farmland of high yield potential (Chapecó) | 8,455 | -17.9% | 31,571 | 6.7% |
| SANTA CATARINA | Chapecó | Farmland of high yield potential (São Miguel d'Oeste) | 11,227 | -16.8% | 29,571 | 11.1% |
| SANTA CATARINA | Chapecó | Farmland of high yield potential (Xanxerê) | 12,289 | -19.5% | 30,571 | 17.9% |
| PARANÁ | Campo Mourão | Farmland of high yield potential (Campo Mourão) | 11,973 | -39.1% | 28,714 | 33.3% |
| PARANÁ | Cascavel | Farmland of high yield potential (Francisco Beltrão) | 9,708 | -30.2% | 26,571 | 40.9% |
| PARANÁ | Cascavel | Farmland of high yield potential (Toledo/Cascavel) | 13,442 | -33.1% | 30,857 | 33.3% |
| PARANÁ | Guarapuava | Farmland of high yield potential (Guarapuava) | 10,251 | -14.3% | 23,143 | 25.0% |
| PARANÁ | Londrina | Farmland, clay soil (Apucarana/Londrina) | 15,732 | -32.5% | 24,857 | 31.8% |
| PARANÁ | Londrina | Farmland, clay soil (Maringá) | 17,230 | -33.0% | 25,143 | 27.3% |
| PARANÁ | Paranavaí | Farmland | 7,932 | -17.9% | 14,100 | 47.8% |
| PARANÁ | Ponta Grossa | Farmland of high yield potential, clay soil (Ponta Grossa/Castro) | 9,574 | -29.9% | 20,929 | 35.3% |
| PARANÁ | Telêmaco Borba | Farmland of high yield potential (Santo Antônio da Platina) | 9,094 | -19.5% | 14,571 | 47.8% |
| PARANÁ | Umuarama | Farmland of high yield potential | 8,253 | -37.7% | 15,000 | 37.5% |
| SÃO PAULO | Itapetininga | Farmland (Itapetininga) | 9,647 | -11.9% | 18,429 | 25.0% |
| SÃO PAULO | Itapetininga | Farmland (Itapeva) | 7,801 | -3.2% | 15,571 | 6.7% |
| SÃO PAULO | Itapetininga | Farmland (Taquarituba) | 9,069 | -8.2% | 16,529 | 28.6% |
| SÃO PAULO | Marília | Farmland of high yield potential | 7,910 | -11.0% | 15,000 | 26.9% |
| SÃO PAULO | Ourinhos | Farmland (Assis) | 11,865 | -11.0% | 21,500 | 24.3% |
| SÃO PAULO | Ourinhos | Farmland (Ourinhos) | 9,887 | -11.0% | 18,857 | 17.6% |
| SÃO PAULO | Pirassununga | Farmland of high yield potential (Casa Branca) | 12,629 | -8.4% | 24,429 | 20.5% |
| SÃO PAULO | São José do Rio Preto | Farmland of high yield potential (Votuporanga) | 8,213 | -9.1% | 17,286 | 12.5% |
| MATO GROSSO DO SUL | Bodoquena | Farmland (Jardim/Bonito) | 4,264 | -33.2% | 7,100 | 27.0% |
| MATO GROSSO DO SUL | Chapadão do Sul | Farmland of high yield potential (Chapadão/Costa Rica) | 10,515 | -47.5% | 19,286 | 70.4% |
| MATO GROSSO DO SUL | Chapadão do Sul | Farmland in plateau (Sonora) | 5,847 | -39.3% | 12,743 | 18.4% |
| MATO GROSSO DO SUL | Dourados | Farmland of high yield potential (Dourados) | 6,496 | -39.3% | 11,143 | 36.8% |
| MATO GROSSO DO SUL | Naviraí | Farmland of high yield potential (Naviraí/Caarapó) | 5,847 | -39.3% | 11,000 | 44.4% |
| MATO GROSSO DO SUL | Rio Brilhante | Farmland of high yield potential (Rio Brilhante/Maracaju) | 7,146 | -39.3% | 13,886 | 66.7% |
| MINAS GERAIS | Uberlândia | Farmland of high yield potential (Ituiutaba) | 5,614 | -17.2% | 11,357 | 36.8% |
| GOIÁS | Catalão | Farmland in plateau | 4,967 | -39.0% | 11,457 | 60.9% |
| GOIÁS | Surrounding of Brasília | Farmland of high yield potential (Cristalina/Formosa) | 5,327 | -64.1% | 15,114 | 41.7% |
| GOIÁS | Surrounding of Goiânia | Farmland of high yield potential | 5,040 | -33.6% | 12,971 | 38.7% |
| GOIÁS | Rio Verde | Farmland of high yield potential (Rio Verde/Mineiros) | 8,235 | -47.2% | 21,000 | 60.0% |
| MATO GROSSO | Alta Floresta | Farmland, soybean (Guarantã/Matupá) | 1,621 | -30.2% | 5,186 | 50.0% |
| MATO GROSSO | Alto Araguaia | Farmland, high altitude (Alto Araguaia/Alto Garça) | 6,247 | -30.2% | 15,643 | 41.7% |
| MATO GROSSO | Aripuanã | Farmland (Porto dos Gaúchos) | 2,921 | -42.2% | 4,543 | 57.1% |
| MATO GROSSO | Barra do Garças | Farmland (Querência) | 2,476 | -24.9% | 6,357 | 60.0% |
| MATO GROSSO | Rondonópolis | Farmland, soybean/cotton (Pedra Preta) | 7,868 | -33.0% | 17,500 | 42.9% |
| MATO GROSSO | Sinop | Farmland, soybean/cotton (Diamantino/Nova Ubiratã) | 5,334 | -46.3% | 16,371 | 38.5% |
| MATO GROSSO | Sinop | Farmland, soybean/cotton (Sorriso/Lucas do Rio Verde/Nova Mutum) | 7,609 | -46.7% | 11,714 | 36.8% |
| MATO GROSSO | Tangará da Serra | Farmland, soybean/cotton (Campo Novo do Parecis) | 5,417 | -28.4% | 11,143 | 50.0% |
| MATO GROSSO | Vila Rica | Farmland, soybean (São José do Xingu/Confresa) | 2,611 | -39.3% | 4,857 | 37.5% |
| BAHIA | East of Bahia | Farmland with 1500 mm annual (Gleba Bom Jesus/Roda Velha/LEM) | 4,606 | -34.8% | 12,671 | 35.9% |
| MARANHÃO | Balsas | Farmland of high yield potential (Balsas/Tasso Fragoso) | 3,237 | -31.7% | 8,900 | 53.4% |
| PIAUÍ | Uruçuí | Farmland of high yield potential (Bom Jesus) | 1,859 | -32.3% | 4,486 | 35.0% |
| PIAUÍ | Uruçuí | Farmland of high yield potential (Uruçuí) | 2,341 | -41.4% | 6,629 | 46.2% |
| TOCANTINS | Araguaína | Farmland, soybean (Campos Lindos) | 3,419 | -18.8% | 7,057 | 37.1% |
| TOCANTINS | Gurupi | Farmland, soybean (Dianápolis) | 3,212 | -35.7% | 10,057 | 85.7% |
| PARÁ | Paragominas | Farmland (Paragominas/Ulianópolis/Dom Eliseu) | 1,697 | -15.9% | 4,557 | 25.0% |
| | | **Mean** | 7,548 | -29.4% | 16,178 | 36.0% |
| | | **Standard Deviation** | 3,689 | 13.1% | 7,457 | 16.5% |
| | | **Minimum** | 1,621 | -64.1% | 4,486 | 6.7% |
| | | **Maximum** | 17,230 | -3.2% | 31,571 | 85.7% |

**Source: Informa FNP**

**Figure 4.2: Period Selection: Land Prices in Selected Soybean, Corn and Cotton Production Regions in Brazil**

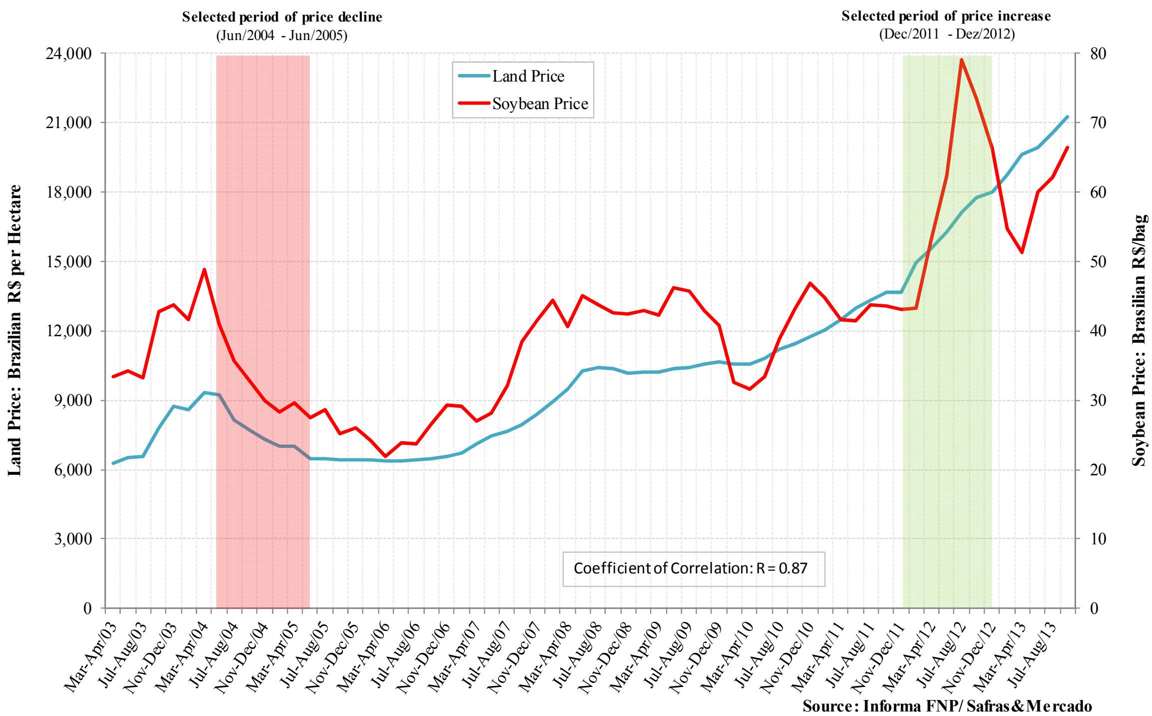



**Source: Informa FNP**

*4.1.2 Soybean Price*

The soybean is one of the most important agricultural commodities in Brazil in terms of production and exports. Soybean price increases in recent years have affected land prices in Brazil. The average soybean price and average land price used in this research are illustrated in Figure 4.3. Correlation between soybean price and land price was 0.87 confirming that soybean price has a strong effect on land prices in Brazil.

**Figure 4.3: Average Land Price and Soybean Prices in Brazil**




Soybean price information used is the average price received by farmers in each period and in each selected region (Table 4.2). Soybean price is expressed in R$/bag and provided by SAFRAS & MERCADO (2013) daily price survey.

From the 52 locations, 28 did not have soybean price information available for the specific municipality where the land price was surveyed. Therefore the soybean price used was from the closest regional market with price availability. The price adjustment considered the direction to the closest market. Transportation costs provided by SIFRECA (2012) was added or subtracted from the price to reach the adjusted price.

## Table 4.2: Soybean Price and Price Change in Each Period and Each Selected Region

| State | Region | Period of Land Price Reduction (Jun/2004 - Jun/2005) | | Period of Land Price Increase (Dec/2011 - Dec/2012) | |
|---|---|---|---|---|---|
| | | Soybean Price (R$/60kg) | Soybean Price Change (%) | Soybean Price (R$/60kg) | Soybean Price Change (%) |
| RIO GRANDE DO SUL | Passo Fundo/Erechim | 35.30 | -36% | 64.43 | 51% |
| RIO GRANDE DO SUL | Santa Rosa/Três Passos | 35.14 | -37% | 63.96 | 52% |
| RIO GRANDE DO SUL | Santo Ângelo/Cruz Alta/Palmeira das Missões | 35.14 | -37% | 64.07 | 52% |
| SANTA CATARINA | Caçador | 35.87 | -34% | 64.14 | 49% |
| SANTA CATARINA | Chapecó | 35.92 | -34% | 64.20 | 49% |
| SANTA CATARINA | São Miguel d'Oeste | 34.78 | -35% | 62.78 | 51% |
| SANTA CATARINA | Xanxerê | 34.30 | -35% | 62.18 | 51% |
| PARANÁ | Campo Mourão | 34.66 | -37% | 63.30 | 60% |
| PARANÁ | Francisco Beltrão | 34.56 | -37% | 63.48 | 61% |
| PARANÁ | Toledo/Cascavel | 34.56 | -37% | 63.48 | 61% |
| PARANÁ | Guarapuava | 34.45 | -34% | 63.62 | 61% |
| PARANÁ | Apucarana/Londrina | 34.82 | -37% | 63.50 | 60% |
| PARANÁ | Maringá | 34.82 | -37% | 63.50 | 60% |
| PARANÁ | Paranavaí | 34.41 | -37% | 62.98 | 61% |
| PARANÁ | Ponta Grossa | 35.34 | -34% | 64.73 | 60% |
| PARANÁ | Telêmaco Borba | 34.62 | -34% | 63.83 | 61% |
| PARANÁ | Umuarama | 34.22 | -37% | 63.06 | 61% |
| SÃO PAULO | Itapetininga | 35.86 | -39% | 65.69 | 55% |
| SÃO PAULO | Itapeva | 35.20 | -39% | 64.87 | 56% |
| SÃO PAULO | Taquarituba | 35.04 | -39% | 64.67 | 56% |
| SÃO PAULO | Marília | 34.46 | -40% | 63.94 | 57% |
| SÃO PAULO | Assis | 34.36 | -40% | 63.82 | 57% |
| SÃO PAULO | Ourinhos | 34.75 | -40% | 64.31 | 57% |
| SÃO PAULO | Pirassununga | 35.41 | -39% | 65.00 | 56% |
| SÃO PAULO | Votuporanga | 33.74 | -40% | 62.91 | 59% |
| MATO GROSSO DO SUL | Jardim/Bonito | 30.77 | -41% | 58.77 | 68% |
| MATO GROSSO DO SUL | Chapadão/Costa Rica | 30.81 | -41% | 58.93 | 55% |
| MATO GROSSO DO SUL | Sonora | 30.81 | -41% | 58.93 | 55% |
| MATO GROSSO DO SUL | Dourados | 32.21 | -40% | 60.57 | 65% |
| MATO GROSSO DO SUL | Naviraí/Caarapó | 32.95 | -40% | 61.49 | 63% |
| MATO GROSSO DO SUL | Rio Brilhante/Maracaju | 31.48 | -41% | 59.93 | 66% |
| MINAS GERAIS | Uberlândia | 33.24 | -41% | 60.54 | 44% |
| GOIÁS | Catalão | 31.76 | -42% | 58.28 | 61% |
| GOIÁS | Cristalina/Formosa | 30.64 | -44% | 58.36 | 51% |
| GOIÁS | Goiânia | 30.60 | -43% | 56.83 | 63% |
| GOIÁS | Rio Verde/Mineiros | 31.88 | -42% | 59.96 | 57% |
| MATO GROSSO | Alta Floresta | 26.01 | -47% | 54.17 | 66% |
| MATO GROSSO | Alto Araguaia | 32.23 | -41% | 60.32 | 57% |
| MATO GROSSO | Porto dos Gaúchos | 26.14 | -47% | 54.32 | 66% |
| MATO GROSSO | Querência | 28.71 | -44% | 55.92 | 63% |
| MATO GROSSO | Rondonópolis | 31.26 | -42% | 59.11 | 59% |
| MATO GROSSO | Diamantino/Nova Ubiratã | 28.56 | -44% | 55.82 | 63% |
| MATO GROSSO | Sorriso/Lucas do Rio Verde/Nova Mutum | 28.36 | -44% | 55.32 | 62% |
| MATO GROSSO | Campo Novo do Parecis | 28.56 | -44% | 55.82 | 63% |
| MATO GROSSO | São José do Xingu/Confresa | 27.21 | -46% | 54.05 | 67% |
| BAHIA | Gleba Bom Jesus/Roda Velha/LEM/Novo Paraná | 28.75 | -37% | 58.64 | 69% |
| MARANHÃO | Balsas/Tasso Fragoso | 29.99 | -43% | 54.77 | 45% |
| PIAUÍ | Bom Jesus | 30.99 | -42% | 53.50 | 42% |
| PIAUÍ | Uruçuí | 30.99 | -42% | 53.50 | 42% |
| TOCANTINS | Campos Lindos | 29.45 | -43% | 54.09 | 46% |
| TOCANTINS | Dianápolis | 29.99 | -43% | 54.77 | 45% |
| PARÁ | Paragominas | 31.13 | -42% | 56.19 | 44% |

**Source: SAFRAS&MERCADO**

*4.1.3 Soybean Yield*

The only yield measure available in Brazil is the State average provided by CONAB(2014). Although it would be ideal for the yield to be available for each analyzed region, the state average can capture some factors such as climatic conditions that can impact land prices between regions and periods. The state average soybean yield (average of two year: the analyzed crop year and the crop year before) were included in the model.

*4.1.4 Distance to the market*

The distance to the market is expressed in kilometers and was measured as the distance for each location to the nearest export market assuming truck transportation routes.

**4.2 Model**

A linear regression model was used to estimate the results. The dependent variable is the annual growth rate of land prices for each region within the two selected periods. The explanatory variable of major interest in this study is distance to the market and its impact on land price growth rates.

Ideally, the distance to the market is measured by the physical distance to the closest consumption market. Agricultural commodities production and consumption patterns are orientated to exports in Brazil, and the distance to the port will define the price of production and income of farmers in the different production regions.

Measuring the distance to the closest market can be a problem and a source of error, especially when there is no single market or when transport systems and costs vary among regions, based on road conditions, availability of rail roads and waterways.

Considering that soybean is the main agricultural commodity in terms of production, consumption and exports in Brazil, a good alternative to the physical distance to the nearest consumption region is the soybean price itself that would include the domestic consumption component.

Soybeans are traded in a very liquid and competitive market in Brazil whose prices are formed at the ports and connected to international markets. Transportation cost is the connection between international prices and prices received by farmers. The price received by farmers can be described as price at the nearest port less transportation costs.

The correlation between soybean price and distance to the market in the regions used in this research was -0.90 in the first period (decreasing land prices) and -0.78 in the second period (increasing land prices), confirming that distance to the market has a strong effect on soybean prices and the distance to the nearest port should be a good indication of the closest market available in Brazil.

The distance to the market is different in the models. The first model considers the physical distance to the nearest export port measured in kilometers, and the second uses the average soybean price for each region as a proxy of distance to the market. Soybean price was selected to test the effectiveness of soybean prices as an indicator of land price behavior in Brazil.

Yield is an important factor that affects land prices. The variable can capture some of the variation due to climatic conditions and land quality that affect farmer's income and land prices in each region.

The linear model using the physical distance to the market is specified as:

$$\textbf{Land Price Change} = \beta^*\textbf{distance to market} + \beta_1{}^*\textbf{soybean yield} + \varepsilon$$

where land price is the annualized price change in percentage, distance to market is the physical distance to the nearest export port measured in kilometers, soybean yield is the average soybean yield of the state where the region is located and $\varepsilon$ is the error term of the equation.

The linear model using the average soybean price for each region as a proxy of distance to market is:

$$\textbf{Land Price Change} = \beta^{*}\textbf{soybean price} + \beta^{*}\textbf{soybean yield} + \varepsilon.$$

The variables in this model are the same with the exception of the soybean price as proxy of distance to the market. Soybean price is the average price received by farmers in each analyzed period and in each selected region.

Both models were estimated for two distinct periods. One a period of land price increase and the other of price decrease. Variables and model fit statistics for physical distance to market are summarized in Table 4.3, and the model using soybean price as a proxy to distance to market is summarized in Table 4.4.

## Table 4.3: Summary Statistics of the Variables Used in the Model Using Physical Distance to Market

| State | Region | Period of Land Price Reduction (Jun/2004 - Jun/2005) | | | Period of Land Price Increase (Dec/2011 - Dec/2012) | | |
|---|---|---|---|---|---|---|---|
| | | Land Price Change (%) | Distance to the Market (kilometers) | Soy Yield (kg/hectare) | Land Price Change (%) | Distance to the Market (kilometers) | Soy Yield (kg/hectare) |
| RIO GRANDE DO SUL | Passo Fundo/Erechim | -38.9 | 559 | 1,021 | 20.9 | 559 | 2,200 |
| RIO GRANDE DO SUL | Santa Rosa/Três Passos | -38.9 | 619 | 1,021 | 18.8 | 619 | 2,200 |
| RIO GRANDE DO SUL | Santo Ângelo/Cruz Alta/Palmeira das Missões | -46.4 | 565 | 1,021 | 25.0 | 565 | 2,200 |
| SANTA CATARINA | Caçador | -17.3 | 361 | 1,970 | 14.6 | 361 | 2,835 |
| SANTA CATARINA | Chapecó | -17.9 | 565 | 1,970 | 6.7 | 565 | 2,835 |
| SANTA CATARINA | São Miguel d'Oeste | -16.8 | 670 | 1,970 | 11.1 | 670 | 2,835 |
| SANTA CATARINA | Xanxerê | -19.5 | 522 | 1,970 | 17.9 | 522 | 2,835 |
| PARANÁ | Campo Mourão | -39.1 | 555 | 2,425 | 33.3 | 555 | 2,907 |
| PARANÁ | Francisco Beltrão | -30.2 | 568 | 2,425 | 40.9 | 568 | 2,907 |
| PARANÁ | Toledo/Cascavel | -33.1 | 595 | 2,425 | 33.3 | 595 | 2,907 |
| PARANÁ | Guarapuava | -14.3 | 356 | 2,425 | 25.0 | 356 | 2,907 |
| PARANÁ | Apucarana/Londrina | -32.5 | 487 | 2,425 | 31.8 | 487 | 2,907 |
| PARANÁ | Maringá | -33.0 | 526 | 2,425 | 27.3 | 526 | 2,907 |
| PARANÁ | Paranavaí | -17.9 | 598 | 2,425 | 47.8 | 598 | 2,907 |
| PARANÁ | Ponta Grossa | -29.9 | 219 | 2,425 | 35.3 | 219 | 2,907 |
| PARANÁ | Telêmaco Borba | -19.5 | 462 | 2,425 | 47.8 | 462 | 2,907 |
| PARANÁ | Umuarama | -37.7 | 659 | 2,425 | 37.5 | 659 | 2,907 |
| SÃO PAULO | Itapetininga | -11.9 | 242 | 2,283 | 25.0 | 242 | 2,766 |
| SÃO PAULO | Itapeva | -3.2 | 361 | 2,283 | 6.7 | 361 | 2,766 |
| SÃO PAULO | Taquarituba | -8.2 | 389 | 2,283 | 28.6 | 389 | 2,766 |
| SÃO PAULO | Marília | -11.0 | 521 | 2,283 | 26.9 | 521 | 2,766 |
| SÃO PAULO | Assis | -11.0 | 442 | 2,283 | 24.3 | 442 | 2,766 |
| SÃO PAULO | Ourinhos | -11.0 | 442 | 2,283 | 17.6 | 442 | 2,766 |
| SÃO PAULO | Pirassununga | -8.4 | 298 | 2,283 | 20.5 | 298 | 2,766 |
| SÃO PAULO | Votuporanga | -9.1 | 601 | 2,283 | 12.5 | 601 | 2,766 |
| MATO GROSSO DO SUL | Jardim/Bonito | -33.2 | 1189 | 2,882 | 27.0 | 1189 | 3,160 |
| MATO GROSSO DO SUL | Chapadão/Costa Rica | -47.5 | 972 | 2,882 | 70.4 | 972 | 3,160 |
| MATO GROSSO DO SUL | Sonora | -39.3 | 972 | 2,882 | 18.4 | 972 | 3,160 |
| MATO GROSSO DO SUL | Dourados | -39.3 | 936 | 2,882 | 36.8 | 936 | 3,160 |
| MATO GROSSO DO SUL | Naviraí/Caarapó | -39.3 | 802 | 2,882 | 44.4 | 802 | 3,160 |
| MATO GROSSO DO SUL | Rio Brilhante/Maracaju | -39.3 | 1005 | 2,882 | 66.7 | 1005 | 3,160 |
| MINAS GERAIS | Uberlândia | -17.2 | 773 | 2,598 | 36.8 | 773 | 2,916 |
| GOIÁS | Catalão | -39.0 | 770 | 2,507 | 60.9 | 770 | 3,130 |
| GOIÁS | Cristalina/Formosa | -64.1 | 1083 | 2,507 | 41.7 | 1083 | 3,130 |
| GOIÁS | Goiânia | -33.6 | 1019 | 2,507 | 38.7 | 1019 | 3,130 |
| GOIÁS | Rio Verde/Mineiros | -47.2 | 1019 | 2,507 | 60.0 | 1019 | 3,130 |
| MATO GROSSO | Alta Floresta | -30.2 | 2320 | 2,882 | 50.0 | 2320 | 3,160 |
| MATO GROSSO | Alto Araguaia | -30.2 | 1180 | 2,882 | 41.7 | 1180 | 3,160 |
| MATO GROSSO | Porto dos Gaúchos | -42.2 | 2240 | 2,882 | 57.1 | 2240 | 3,160 |
| MATO GROSSO | Querência | -24.9 | 1815 | 2,882 | 60.0 | 1815 | 3,160 |
| MATO GROSSO | Rondonópolis | -33.0 | 1365 | 2,882 | 42.9 | 1365 | 3,160 |
| MATO GROSSO | Diamantino/Nova Ubiratã | -46.3 | 1794 | 2,882 | 38.5 | 1794 | 3,160 |
| MATO GROSSO | Sorriso/Lucas do Rio Verde/Nova Mutum | -46.7 | 1939 | 2,882 | 36.8 | 1939 | 3,160 |
| MATO GROSSO | Campo Novo do Parecis | -28.4 | 2050 | 2,882 | 50.0 | 2050 | 3,160 |
| MATO GROSSO | São José do Xingu/Confresa | -39.3 | 2012 | 2,882 | 37.5 | 2012 | 3,160 |
| BAHIA | Gleba Bom Jesus/Roda Velha/LEM | -34.8 | 983 | 2,730 | 35.9 | 983 | 3,110 |
| MARANHÃO | Balsas/Tasso Fragoso | -31.7 | 776 | 2,679 | 53.4 | 776 | 3,018 |
| PIAUÍ | Bom Jesus | -32.3 | 932 | 2,652 | 35.0 | 932 | 2,912 |
| PIAUÍ | Uruçuí | -41.4 | 802 | 2,652 | 46.2 | 802 | 2,912 |
| TOCANTINS | Campos Lindos | -18.8 | 874 | 2,525 | 37.1 | 874 | 3,049 |
| TOCANTINS | Dianápolis | -35.7 | 1606 | 2,525 | 85.7 | 1606 | 3,049 |
| PARÁ | Paragominas | -15.9 | 570 | 2,850 | 25.0 | 570 | 2,829 |
| | **Mean** | -29.4 | 884 | 2,460 | 36.0 | 884 | 2,939 |
| | **Standard Deviation** | 13.1 | 535 | 449 | 16.5 | 535 | 235 |
| | **Minimum** | -64.1 | 219 | 1,021 | 6.7 | 219 | 2,200 |
| | **Maximum** | -3.2 | 2320 | 2,882 | 85.7 | 2320 | 3,160 |

## Table 4.4: Summary Statistics of the Variables Used in the Model Using Soybean Price as a Proxy to Distance to the Market

| State | Region | Period of Land Price Reduction (Jun/2004 - Jun/2005) | | | Period of Land Price Increase (Dec/2011 - Dec/2012) | | |
|---|---|---|---|---|---|---|---|
| | | Land Price Change (%) | Soybean Price (R$/60kg) | Soy Yield (kg/hectare) | Land Price Change (%) | Soybean Price (R$/60kg) | Soy Yield (kg/hectare) |
| RIO GRANDE DO SUL | Passo Fundo/Erechim | -38.9 | 35.30 | 1,021 | 20.9 | 64.43 | 2,200 |
| RIO GRANDE DO SUL | Santa Rosa/Três Passos | -38.9 | 35.14 | 1,021 | 18.8 | 63.96 | 2,200 |
| RIO GRANDE DO SUL | Santo Ângelo/Cruz Alta/Palmeira das Missões | -46.4 | 35.14 | 1,021 | 25.0 | 64.07 | 2,200 |
| SANTA CATARINA | Caçador | -17.3 | 35.87 | 1,970 | 14.6 | 64.14 | 2,835 |
| SANTA CATARINA | Chapecó | -17.9 | 35.92 | 1,970 | 6.7 | 64.20 | 2,835 |
| SANTA CATARINA | São Miguel d'Oeste | -16.8 | 34.78 | 1,970 | 11.1 | 62.78 | 2,835 |
| SANTA CATARINA | Xanxerê | -19.5 | 34.30 | 1,970 | 17.9 | 62.18 | 2,835 |
| PARANÁ | Campo Mourão | -39.1 | 34.66 | 2,425 | 33.3 | 63.30 | 2,907 |
| PARANÁ | Francisco Beltrão | -30.2 | 34.56 | 2,425 | 40.9 | 63.48 | 2,907 |
| PARANÁ | Toledo/Cascavel | -33.1 | 34.56 | 2,425 | 33.3 | 63.48 | 2,907 |
| PARANÁ | Guarapuava | -14.3 | 34.45 | 2,425 | 25.0 | 63.62 | 2,907 |
| PARANÁ | Apucarana/Londrina | -32.5 | 34.82 | 2,425 | 31.8 | 63.50 | 2,907 |
| PARANÁ | Maringá | -33.0 | 34.82 | 2,425 | 27.3 | 63.50 | 2,907 |
| PARANÁ | Paranavaí | -17.9 | 34.41 | 2,425 | 47.8 | 62.98 | 2,907 |
| PARANÁ | Ponta Grossa | -29.9 | 35.34 | 2,425 | 35.3 | 64.73 | 2,907 |
| PARANÁ | Telêmaco Borba | -19.5 | 34.62 | 2,425 | 47.8 | 63.83 | 2,907 |
| PARANÁ | Umuarama | -37.7 | 34.22 | 2,425 | 37.5 | 63.06 | 2,907 |
| SÃO PAULO | Itapetininga | -11.9 | 35.86 | 2,283 | 25.0 | 65.69 | 2,766 |
| SÃO PAULO | Itapeva | -3.2 | 35.20 | 2,283 | 6.7 | 64.87 | 2,766 |
| SÃO PAULO | Taquarituba | -8.2 | 35.04 | 2,283 | 28.6 | 64.67 | 2,766 |
| SÃO PAULO | Marília | -11.0 | 34.46 | 2,283 | 26.9 | 63.94 | 2,766 |
| SÃO PAULO | Assis | -11.0 | 34.36 | 2,283 | 24.3 | 63.82 | 2,766 |
| SÃO PAULO | Ourinhos | -11.0 | 34.75 | 2,283 | 17.6 | 64.31 | 2,766 |
| SÃO PAULO | Pirassununga | -8.4 | 35.41 | 2,283 | 20.5 | 65.00 | 2,766 |
| SÃO PAULO | Votuporanga | -9.1 | 33.74 | 2,283 | 12.5 | 62.91 | 2,766 |
| MATO GROSSO DO SUL | Jardim/Bonito | -33.2 | 30.77 | 2,882 | 27.0 | 58.77 | 3,160 |
| MATO GROSSO DO SUL | Chapadão/Costa Rica | -47.5 | 30.81 | 2,882 | 70.4 | 58.93 | 3,160 |
| MATO GROSSO DO SUL | Sonora | -39.3 | 30.81 | 2,882 | 18.4 | 58.93 | 3,160 |
| MATO GROSSO DO SUL | Dourados | -39.3 | 32.21 | 2,882 | 36.8 | 60.57 | 3,160 |
| MATO GROSSO DO SUL | Naviraí/Caarapó | -39.3 | 32.95 | 2,882 | 44.4 | 61.49 | 3,160 |
| MATO GROSSO DO SUL | Rio Brilhante/Maracaju | -39.3 | 31.48 | 2,882 | 66.7 | 59.93 | 3,160 |
| MINAS GERAIS | Uberlândia | -17.2 | 33.24 | 2,598 | 36.8 | 60.54 | 2,916 |
| GOIÁS | Catalão | -39.0 | 31.76 | 2,507 | 60.9 | 58.28 | 3,130 |
| GOIÁS | Cristalina/Formosa | -64.1 | 30.64 | 2,507 | 41.7 | 58.36 | 3,130 |
| GOIÁS | Goiânia | -33.6 | 30.60 | 2,507 | 38.7 | 56.83 | 3,130 |
| GOIÁS | Rio Verde/Mineiros | -47.2 | 31.88 | 2,507 | 60.0 | 59.96 | 3,130 |
| MATO GROSSO | Alta Floresta | -30.2 | 26.01 | 2,882 | 50.0 | 54.17 | 3,160 |
| MATO GROSSO | Alto Araguaia | -30.2 | 32.23 | 2,882 | 41.7 | 60.32 | 3,160 |
| MATO GROSSO | Porto dos Gaúchos | -42.2 | 26.14 | 2,882 | 57.1 | 54.32 | 3,160 |
| MATO GROSSO | Querência | -24.9 | 28.71 | 2,882 | 60.0 | 55.92 | 3,160 |
| MATO GROSSO | Rondonópolis | -33.0 | 31.26 | 2,882 | 42.9 | 59.11 | 3,160 |
| MATO GROSSO | Diamantino/Nova Ubiratã | -46.3 | 28.56 | 2,882 | 38.5 | 55.82 | 3,160 |
| MATO GROSSO | Sorriso/Lucas do Rio Verde/Nova Mutum | -46.7 | 28.36 | 2,882 | 36.8 | 55.32 | 3,160 |
| MATO GROSSO | Campo Novo do Parecis | -28.4 | 28.56 | 2,882 | 50.0 | 55.82 | 3,160 |
| MATO GROSSO | São José do Xingu/Confresa | -39.3 | 27.21 | 2,882 | 37.5 | 54.05 | 3,160 |
| BAHIA | Gleba Bom Jesus/Roda Velha/LEM | -34.8 | 28.75 | 2,730 | 35.9 | 58.64 | 3,110 |
| MARANHÃO | Balsas/Tasso Fragoso | -31.7 | 29.99 | 2,679 | 53.4 | 54.77 | 3,018 |
| PIAUÍ | Bom Jesus | -32.3 | 30.99 | 2,652 | 35.0 | 53.50 | 2,912 |
| PIAUÍ | Uruçuí | -41.4 | 30.99 | 2,652 | 46.2 | 53.50 | 2,912 |
| TOCANTINS | Campos Lindos | -18.8 | 29.45 | 2,525 | 37.1 | 54.09 | 3,049 |
| TOCANTINS | Dianápolis | -35.7 | 29.99 | 2,525 | 85.7 | 54.77 | 3,049 |
| PARÁ | Paragominas | -15.9 | 31.13 | 2,850 | 25.0 | 56.19 | 2,829 |
| | **Mean** | -29.4 | 32.45 | 2,460 | 36.0 | 60.37 | 2,939 |
| | **Standard Deviation** | 13.1 | 2.71 | 449 | 16.5 | 3.84 | 235 |
| | **Minimum** | -64.1 | 26.01 | 1,021 | 6.7 | 53.50 | 2,200 |
| | **Maximum** | -3.2 | 35.92 | 2,882 | 85.7 | 65.69 | 3,160 |

# CHAPTER V: RESULTS

Land price volatility in different regions of Brazil was analyzed. The physical distance to the market model was analyzed first. A second model uses the average soybean price for each region as a proxy of distance to market to test the effectiveness of soybean prices as an indicator of land price behavior in Brazil. Additionally, other results and economic implications were discussed.

## 5.1 Model using physical distance to market

The OLS results for the physical distance to market model are summarized in Table 5.1. Although the model has a low $R^2$ for the declining land price period (0.23) and for the increasing land price period (0.37), the model explanatory variable of primary interest (distance to market) is statistically significant at the 1% level for both periods (increasing and declining land values) and with the expected sing for both periods, being positive when land values are rising and negative when values are falling.

Soybean yield was statistically significant for the increasing land price period.

**Table 5.1: Regression Results for the Model Explaining the Growth and Decline of Land Values in Brazil, April 2004 to June 2005 and from December 2011 to December 2012**

| | Declining Price Period | | Increasing Price Period | |
|---|---|---|---|---|
| | Model | t-statistics | Model | t-statistics |
| Intercept | -26.48 | -2.81 | -50.01 | -1.87 |
| Distance to the market | -0.013 | -3.60 ** | 0.010 | 2.22 ** |
| Soybean yield | 0.004 | 0.81 | 0.026 | 2.70 * |
| $R^2$ | 0.23 | | 0.37 | |
| *n* | 52 | | 52 | |

* (**) Significant at 5% (1%) level, two tail test

The effect of the variable distance to market was stronger in the first period (decreasing land price), where each 100 kilometer increase in distance to the market is associated with a decrease in 1.3 percentage points in land prices. If distance to the market increases from 884 to 984 kilometers, the rate of land price decline will increase from -29.4% to -30.7%.

In the second period analyzed (increasing land prices) for each 100 kilometer increase in distance to market, the growth rate of land price increased 1.0 percentage point. Thus, if distance to market increases from 884 to 984 kilometers the land price growth rate increases from 36.0% to 37.0%.

The effect of the variable soybean yield was statistically significant in the second period analyzed (rising land price) with better yields associated with greater land price increases. For each 100 kg/hectare (1.5 bushels/acre) increase in yield, the land price growth rate increased 2.6 percentage points. If yield increases from 2939 kg/hectare (43.7

bushels/acre) to 3039 kg/hectare (45.2 bushels/acre) the land price growth rate increases from 36.0% to 38.6%.

The empirical results from the model support the hypothesis that areas located further from markets experienced relatively greater changes in land prices and the effect is stronger in the declining land price period.

**5.2 Model using soybean price as a proxy to distance to market.**

The OLS results for the model using soybean price as a proxy to the physical distance to the market are summarized in Table 5. 2. The model has a slightly better fit when compared with the physical distance to the market, with an $R^2$ of 0.25 for the declining land price period and 0.40 for the increasing land price period.

The soybean price is statistically significant at the 1% level for both periods (increasing and decreasing land price values) being negative when land values are rising and positive when values are falling. The signs are the opposite compared with the physical distance to the market because as distance increases, soybean prices fall.

Soybean yield is statistically significant in the increasing land price period.

**Table 5. 2: Regression Results for the Model Explaining the Growth and Decline of Land Values in Brazil Considering Soybean Price as a Proxy of Distance to market, April 2004 to June 2005 and December 2011 to December 2012**

| | Declining Price Period | | Increasing Price Period | |
|---|---|---|---|---|
| | Model | t-statistics | Model | t-statistics |
| Intercept | -145.65 | -4.22 | 59.02 | 1.02 |
| Soybean Price | 3.032 | 3.84 ** | -1.548 | -2.60 ** |
| Soybean yield | 0.007 | 1.52 | 0.024 | 2.46 ** |
| $R^2$ | 0.25 | | 0.40 | |
| *n* | 52 | | 52 | |

* (**) Significant at 5% (1%) level, two tail test

The effect of the soybean price variable as a proxy for the physical distance to market was stronger in the first period (decreasing land prices), where each Brazilian Real per bag decrease in soybean price (going to a more distant location) was associated with a 3.0 percentage point decline in land prices. If soybean prices fall from 32.0 R$/bag to 31.0 R$/bag, the land price decline will change from -39.0% to -42.0%.

In the second period analyzed (increasing land prices) for each Brazilian Real per bag decrease in soybean price (going to a more distant location) the growth rate of land price increased 1.5 percentage points. If soybean prices fall from 60.0 R$/bag to 59.0 R$/bag the land price growth rate will increase from 36.6% to 38.1%.

Higher explanatory power of the model using soybean price as a proxy to the physical distance to market confirmed that it is a good alternative to the physical distance to the nearest consumption region in Brazil.

The soybean yield was statistically significant at the 1% level in the second period analyzed (rising land price), with better yields associated with greater land price increases. For each 100 kg/hectare (1.5 bushels/acre) increase in yield, the growth rate of land price increased 2.4 percentage points. If yield increases from 2939 kg/hectare (43.7 bushels/acre) to 3039 kg/hectare (45.2 bushels/acre), the land price growth rate increases from 36.0% to 38.4%.

In addition to the model using physical distance to market, the empirical results using soybean price as a proxy for the physical distance to market support the hypothesis that areas located further from markets experienced greater changes in land prices with the effect being stronger in the declining land price period.

Using soybean price as a proxy to the physical distance to market resulted in slightly better model explanatory power, confirming that it is a good alternative to the physical distance to the market by adding the domestic consumption component to the equation.

### 5.3 Other results and economic implications

One of the regions of major interest in Brazil is the State of Mato Grosso because it is the largest soybean production region, the fastest growing area in Brazil and is one of the least favorable locations from a transportation standpoint.

For the period of increasing land values, the predicted annual increase from the model is 51%, higher than the observed value of 46%. The average farmland price of Mato Grosso was R$ 8,222 per hectare in December 2011 implying a predicted increase of values of R$ 4,203 per hectare per year.

For the selected period of falling land prices, the predicted annual decline in land prices is 41% per year, which is more than the observed value of 36%. The average value of Mato Grosso farm real estate was R$ 6,124 per hectare in June 2004. This implies a predicted decline of values by R$ 2,486 per hectare per year.

The less favorable location in the study is Alta Floresta in Mato Grosso State that is located at 2,320 kilometers from the closest export port. Considering the coefficients obtained in the period of declining land prices, the predicted land price reduction was 47%, a 28 percentage point greater decline compared to the region of Ponta Grossa in Paraná State, which is the most favorable location, situated about 219 kilometers from the closest port. This region has a predicted land price reduction of 19% in the period of declining land prices.

Considering the coefficients obtained in the period of increasing land prices, Alta Floresta's predicted land price increase of 56% a year was 27% higher than Ponta Grossa, which had a predicted land price increase of 29% in the period of rising land prices.

# CHAPTER VI: CONCLUSIONS AND RECOMENDATIONS

Price cycles in farmland historically have caused severe impacts on agricultural economies. In the U.S., where farmland price change overtime has been extensively studied, researchers have developed models and concepts to better understand the behavior of land markets.

In Brazil, little research has been done regarding land price changes. Considering that the majority of new land is usually far from consumer markets (domestic markets and ports), a particular issue for investors is to better understand land price dynamics in those areas.

The empirical results of this research supported the hypothesis that areas far from the markets are exposed to greater changes in land prices and these areas can be especially affected by land price cycles. These regions will have greater incentives for expansion and increased investments in periods of rising land prices. In addition, these regions will have an increased risk for disinvestment and failure in periods of land price contraction.

The effect of distance to market on land price volatility was larger in the period of land price decline. Land price volatility can be a source of problems for farmers and investors, especially in periods of falling prices in locations far from markets where the impact of price reduction is higher than in other locations, suggesting that farmers and investors should pay special attention to investment decisions in these regions.

It is difficult to predict when a cycle of expansion or crisis will start or finish, but the present study helps to understand potential land price behavior when such events happen.

Future studies could include other variables such as land characteristics, the inclusion of undeveloped land (native and pasture) and other variables that may increase the model predictability.

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