EFFECTS OF SUGARCANE EXPANSION ON DEVELOPMENT AND LAND USE AND LAND COVER CHANGE (LULCC) IN BRAZIL: A CASE STUDY IN THE STATE OF GOIÁS

by

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Abstract

As concerns increase over climate change, energy independence, and higher fuel prices, Brazilian sugarcane ethanol is seen as a part of a clean energy future. Brazilian sugarcane ethanol was developed with a long history of government support, and with the introduction of the flex fueled car in 2003, demand rose dramatically. These factors have helped sugarcane expand beyond its traditional regions of Brazil into the Cerrado. More recently however, private capital from both domestic and foreign companies have started investing in Brazilian agriculture and these investments have helped fuel the sugarcane expansion into the Cerrado in the last 15 years. Over 22 sugarcane mills have been constructed in the Brazilian state of Goiás, located in the heart of the Cerrado. The increased investments driving the expansion of sugarcane into the Cerrado brings numerous questions regarding its environmental and social impacts. Thus, the goal of this thesis is to understand how the structural organization of the sugarcane ethanol mills' affects development at a municipality level in the state of Goiás, Brazil. More specifically, this thesis has two objectives; to evaluate the effects of the sugarcane mills' influence on land use and land cover change in these municipalities; and to compare how domestic owned mills, foreign owned mills, and jointly owned mills affect socioeconomic development on the municipalities. Three municipalities were analyzed, Edéia, Caçu, and Quirinópolis. Results showed that land use and land cover change varied by municipality. The majority of Edéia's sugarcane expansion came from lands already in agricultural use. On the other hand, Caçu's and Quirinópolis's sugarcane expansion came from pasture lands. However, throughout all the municipalities, sugarcane expansion over native vegetation was small. All three municipalities increased their socioeconomic development levels over the past 20 years as reported on the Human Development Index. In addition, urban survey responses revealed that the residents of

Edéia perceived the sugarcane mill had made their lives better than respondents in either Quirinópolis or Caçu. However, this analysis covers only a brief period of time, and future analysis of these, and other municipalities that host sugarcane mills throughout the Cerrado will be needed.

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Chapter 1 - Introduction

Brazil is a country with a variety of biomes, many of which are currently undergoing an enormous transformation due to the modernization of Brazil's agriculture (Rada, 2013; Pereira et al., 2012). Agriculture in Brazil has historically been seen as traditional, but starting in 1970s the traditional practices began to change (Pereira et al., 2012). Government investments in new programs and technologies brought Brazil's vast economically and agriculturally unproductive spaces into modern cultivation (Pereira et al., 2012; Klink and Moreira, 2002). The development of new crops suitable for tropical soils and climates, the development of roads and other forms of infrastructure, and the creation of credit programs to stimulate development were all vital to Brazil's agricultural modernization (Pereira et al., 2012; Klink and Moreira, 2002; Fearnside, 2001). Among these once unproductive spaces is the Cerrado, the Brazilian savanna. Characterized by a diversity of grass and forested lands occupying near 24% of the county's area, the Cerrado has become a major agricultural region (Rada, 2013). Although not as famous as the Amazon, the Cerrado contains five percent of the entire biodiversity on the planet and is consider a biodiversity hotspot (Mittermeier et al., 1999; World Wildlife Fund, 2011).

As concerns about climate change, energy independence and clean energy have increased, the Cerrado has become the new frontier for sugarcane expansion (Sauer and Leite, 2012; Wilkinson and Herrera, 2010; Rico et al., 2010). Production of sugarcane in the state of Goiás, which is centrally located in the Cerrado, increased dramatically from 219,530 metric tons to 54,903,085 metric tons from 1975/1976 to 2011 as a result of domestic investments (Pereira et al. 2012, IBGE, 2012). Proponents of the sugarcane industry argue that investments in ethanol mills bring important economic incentives, such as jobs, better roads and more sustainable liquid fuels for domestic and international consumption (Martinelli et al., 2011; Sawyer, 2008; AETS, 2013). However, the expansion of sugarcane also exerts pressure on lands used for producing milk, cattle and food crops, which in turn displaces these crops and animals to other regions (Novo et al., 2010; Pereira et al., 2012). Additionally, sugarcane expansion leads to the loss of Cerrado vegetation, thus threatening many endemic animals and the most diverse variety of plants in any savanna biome worldwide (Ratter et al., 1997). Other studies claim that sugarcane expansion has come at the expense of degraded pastures that are no longer productive (Nassar et al., 2008; Adami et al., 2012). Some experts even argue that sugarcane production creates major problems such as land concentration, income concentration, water and soil pollution, and poor working conditions. These problems raise concerns about the sugarcane industry's impact on development (Ribeiro, 2013; Lehtonen, 2011; Wilkinson and Herrera, 2010; Martinelli and Filoso, 2008; Sawyer, 2008; Goldemberg, 2008).

Despite the potential problems described above, some experts report that during the past fifteen years domestic and foreign investments have promoted new jobs and technologies in the sugarcane ethanol sector (de Moraes and Zilberman, 2014). For instance, in 2003 one of these new technologies, the flex-fueled car, helped to increase the use of ethanol in Brazil. Owners of these cars were offered the option of using gasoline (with 20-25% anhydrous ethanol), hydrated ethanol, or any combination of the two depending on availability, price and performance. Today 95% of all new car sales in Brazil are flex-fueled (Rico et al., 2010; Wilkinson and Herrera, 201; Nogueira and Capaz, 2013; Goldemberg, 2013). As a result of this, and high gasoline prices, the production of ethanol skyrocketed; in 2003 Brazil produced 15 billion liters of ethanol, and by 2009 the production increased to 25 billion liters of ethanol (Wilkinson and Herrera; 2010). The high demand for biofuels has stimulated new investments that seek to expand new processes of production, such as cellulosic feedstocks and co-electrical generation, and new products made from sugarcane, such as plastics and jet fuel (de Moraes and Zilberman, 2014). The increases in investments from both domestic and foreign companies has attracted the attention to the impacts of these investments into rural areas (Wilkinson and Herrera, 2010, Martinelli and Filoso, 2008). Although Foreign Direct Investment (FDI) impacts have been studied at a national level, this study is at a much smaller scale. Furthermore, no one has yet compared and contrasted how the ownership structure of sugarcane ethanol mills impacts municipalities, both socioeconomically and regarding land use and land cover change.

The goal of this study is to understand how the structural organization of the sugarcane ethanol mills' affects development at a municipality level in the state of Goiás, Brazil. More specifically, this thesis has two objectives: first, it will evaluate the sugarcane mills' influence on land use land cover change in these municipalities using remote sensing and Geographic Information System techniques; second, it will compare how domestically owned mills, foreign-owned mills, and jointly owned mills affect socioeconomic development on the municipalities drawing from socioeconomic data and survey data collected from urban residents and farmers from the study areas.

This study is divided into six chapters. The first chapter will give a brief introduction to the topic under study. The second chapter will describe the development of the sugarcane industry in Brazil. Chapter three will review the literature on the six focal points of this thesis: (1) explains the expansion of agriculture into the Brazilian Cerrado; (2) reviews sugarcane's impact on agriculture and the environment in rural places; (3) summarizes the socioeconomic implications of sugarcane expansion; (4) explains the implications of economic investments on agriculture and rural places ; (5) discusses the heated debate on the effects of foreign direct investment on economic growth; (6) explains how foreign direct investment has impacted

Brazilian agriculture. Chapter four discusses the research and sample design, study area, and data collection. Chapter five presents and discusses the research results on how the sugarcane mills have influenced the land use land cover change, how the ownership structure of the sugarcane mill impacted socioeconomic development, and the perceptions that urban residents and farmers have of sugarcane production in their communities. Chapter six provides a final analysis and conclusion for this study.

Chapter 2 - Development of the Sugarcane Industry in Brazil.

This chapter will explain the development and expansion of the sugarcane industry in Brazil. To accomplish this, I will first discuss the industry's colonial roots, growth, protection, and development of neoliberal policies. Next, I will explain the consolidation and concentration of the industry. Finally, I will describe how Foreign Direct Investment has helped fuel the expansion of sugarcane into the Brazilian Cerrado.

2.1 From Colonial Roots to Liberal Policies

Sugarcane production in Brazil has its roots in the colonial days of the 16th and 17th centuries. Portuguese immigrants utilized slave labor to plant, cultivate, and harvest sugarcane in the northeastern region of Brazil for sugar to be sold in Europe (Leite et al., 2009; Nogueira and Capaz, 2013). This process continued until the early 20th century when modern technology revolutionized the development of sugarcane into a source of fuel. As early as the 1920s Brazilians used sugarcane for ethanol (Wilkinson and Herrera, 2010). It is important to note that there are two forms of ethanol: anhydrous, which is used as an additive to gasoline, and hydrous, which can be used on its own for fuel or used in other applications. (Moreira and Goldemberg, 1999). In the 1930s, the federal government of Brazil began to produce anhydrous ethanol blends of 5% with gasoline. As a result, the increase in demand and utility for sugarcane helped spread the crop from its original home in northeast Brazil into the southeast (Leite et al., 2009; Rico et al., 2010; Nogueira and Capaz, 2013).

Due to the increased popularity of sugarcane, Brazilian government created a new agency, the Institute of Sugar and Alcohol (IAA), to help protect sugarcane farmers from overproduction of sugarcane and to promote the production of fuel ethanol (de Moraes and

Zilberman, 2014). The IAA was developed in 1933 during the world economic depression to help solve the overproduction problem. The IAA task was centered in coordinating annual planning and production control and by dealing with domestic and foreign consumption of Brazilian sugarcane (de Moraes and Zilberman, 2014). In order to control the supply of sugar, the IAA instituted a nationwide ban on any new sugar production facilities without IAA authorization. The institute further registered all sugarcane facilities and placed limits of production for each state set by the average production over the past five years. These actions all helped to keep the northeastern region of Brazil in control of the market (de Moraes and Zilberman, 2014).

This foresight into developing the ethanol industry was extremely important for the entire economy of Brazil, especially with the start of World War II less than a decade later. In 1933 there was only one fuel-grade distillery capable of producing ethanol in Brazil; by 1945 this number increased to 54 (Hira and de Oliveira, 2009). Due to oil shortages, the blend rate of anhydrous ethanol to gasoline was fixed at 20%, but this rate reached as high as 40% in northeastern Brazil (Hira and Oliveira 2009; de Moraes and Zilberman, 2014). Difficulties with transporting sugarcane from the northeastern region of Brazil during the war caused the government to relax its production caps for each state during this time, which indirectly helped shift the production of sugarcane in Brazil (de Moraes and Zilberman, 2014). By 1951, sugarcane production in the center-south region of Brazil had surpassed the northeast (Hira and de Oliveira, 2009). The center-south region of Brazil had better financial security and stronger purchasing power. This region also had the advantage of close proximity to a modern industry park in São Paulo, a larger consumer base, and positive climate and agricultural conditions (de

Moraes and Zilberman, 2014). These numerous advantages greatly aided sugarcane production's transition to the center-south region of Brazil.

As the center-south region became the dominant producer of sugarcane in Brazil, the industry experienced an increase in production nationwide. As a result, Brazilian sugar exports expanded exponentially. This expansion came after 1960, due to the crisis within the Caribbean. The United States embargo of Cuban sugarcane caused a 250% increase for Brazilian sugar exports from 1965–1974 (Hira and de Oliveira, 2009). Unfortunately, the combination of excellent weather conditions and the reduction of the national blend rate of anhydrous ethanol to as low as 7.5%, led to an overproduction problem (de Moraes and Zilberman, 2014; Nogueira et al., 2008). Interests in ethanol as a fuel source tampered off until another major crisis occurred. This time the crisis was not triggered by a war, but by the sharp increase in oil prices during the 1970s.

A production boycott started by the newly formed Organization of Petroleum Exporting Countries (OPEC) in 1973 increased the international price of oil from US $2.90/barrel in 1973 to US$11.65/barrel in 1974 (Andrietta et al., 2007). This sharp increase in oil prices was important for the Brazilian economy, as Brazil was importing 80% of petroleum in 1970 (Andrietta et al., 2007). As a result, the large-scale production of sugarcane as a fuel source took off in 1975 when then military President Geisel introduced a governmental program called the National Alcohol Program (Proálcool) (Rico et al., 2010; Nogueira and Capaz 2013). With the introduction of Proálcool, Brazil also started to explore its own petroleum resources and hydroelectric power capabilities, and as a result the country started its journey towards becoming a more energy-secure nation (Leite et al., 2009). Proálcool also stimulated the market for ethanol and supported sugarcane growers, thus increasing the amount of sugarcane being produced in the country by aiming to raise the national ethanol blend rate with gasoline to 25% until 1980 (Hira, 2011). Some of the incentives that Proálcool developed included guaranteeing lower consumer prices for hydrated ethanol than gasoline, guaranteeing competitive prices for ethanol producers regardless of sugar prices, encouraging financing for mills to increase their production capacity, reducing taxes on new cars, and making the ethanol supply accessible even outside of the growing season (Nogueira and Capaz, 2013).

The government's financial support for mills was necessary to meet the growing domestic demand of ethanol caused by the new blend rate mandate. This demand was met in part by building new mills or by restructuring old mills to produce both sugar and ethanol or only ethanol. As a result, by 1980, 209 new mills were constructed and Brazil produced 3.4 billion liters of ethanol (Shikida and Bacha, 1999; MAPA, 2013) In the beginning many people were skeptical of Proálcool due to the enormous amounts of subsidies required to continue the program, but these skeptics soon faded out when the second oil crisis of 1979 hit and the program proved its invaluableness (Hira, 2011).

The second oil crisis was a result of the OPEC countries fighting for control over the organization (de Moraes and Zilberman, 2014). This fight for control led to a dramatic increase in the price of oil. In 1978 OPEC price per barrel was at US$12.70 and in 1979 which was the beginning of the crisis, it had doubled to US$24 (de Moraes and Zilberman, 2014). This crisis had an enormous impact on Brazilian economy. Oil imports had thrown off their trade balance, inflation rose to 77%, and the external debt increased to 27% of their GDP (de Moraes and Zilberman, 2014). The Brazilian government's Proálcool, as well as other sources of alternative energies, became even more influential to Brazilian fuel and energy supply as a result of the crisis. Proálcool had an ambitious two part plan to produce 10.7 billion liters of sugarcane ethanol by 1985, and to produce a new car fleet that would be powered by hydrous sugarcane ethanol (Goldemberg, 2006; Hira and de Oliveira, 2009; La Rovere et al., 2011). Sugarcane farmers were given government subsidies to sell their sugarcane for ethanol production rather than sugar production. Other government subsidies were given to car manufactures to produce ethanol-fueled vehicles and to provide the infrastructure necessary to deliver hydrous ethanol to consumers. Financial support was offered to consumers as well through reduced ethanol prices at 65% of the price of gasoline and tax credits to purchase ethanol-fueled vehicles (Hira and de Oliveira, 2009; de Moraes and Zilberman, 2014).

These measures gave the Brazilian government and consumers relief. By 1986, blending rates of anhydrous ethanol to gasoline increased to 20-25% and the introduction of heavily government subsidized alcohol-fueled vehicles led to 12 billion liters of ethanol being produced and ethanol-run cars accounting for 90% of all new car sales between 1983 and 1989 (Wilkinson and Herrera, 2010; Hira, 2011; de Moraes and Zilberman, 2014). Proálcool also had an important impact on the production of sugarcane for ethanol as a priority rather than an afterthought; by the 1985-1986 season, 60% of sugarcane was being used for ethanol (de Moraes and Zilberman, 2014). However, this phase would soon come to an end as number of new problems started to threaten the ethanol industry.

In 1985 the ethanol industry in Brazil came under attack as oil prices lowered, problems with alcohol-fueled cars multiplied, and sugar prices rose (Wilkinson and Herrera, 2010; Nogueira and Capaz, 2013). These problems all occurred during the international debt crisis, leaving Brazil's government unable to continue to subsidize the sugarcane ethanol industry and other government agencies. Without these subsidies, many sugarcane growers chose to produce sugar instead of ethanol (Nazmi, 1998; Wilkinson and Herrera, 2010; Nogueira and Capaz, 2013). During this period the military government of Brazil opened way for democratic elections and liberalized trade (Nazmi, 1998; Rico et al., 2010). This process was driven by the government's goals to encourage modernization in Brazil through import substitution and the expansion of its export sector (Nazmi, 1998). From 1991 to 1999 this liberalization led to the removal of most subsidies and price fixing for sugar and ethanol and the end of the Proalcool Program and the Instituto de Açúcar e Álcool (IAA). These commodities were now linked to the global-market (Nazmi, 1998; Rico et al., 2010; Nogueira and Capaz 2013). Without the support of government programs and subsidies, Brazil had no choice but to import ethanol produced in the United States. By the year 2000, ethanol-driven cars accounted for less than 1% of all new car sales in Brazil (Goldemberg, 2013).

2.2 The Consolidation of the Ethanol Industry

The changes in the Brazilian economy, especially in relation to the sugarcane industry, led to the consolidation and concentration of the industry, particularly in the state of São Paulo (Lehtonen, 2011). Without government subsidies and protections, the more socioeconomically disadvantaged northeast of Brazil suffered more than any other region. In 1982-1983 the northeast accounted for 30.1% of sugarcane production in Brazil, but by 1994-1995 production reduced to 18.2%. By 2012 the production in the northeast was down to 13% (Lehtonen, 2011, IBGE, 2012). The consolidation of the sugarcane industry in São Paulo took advantage of this pro-business climate during the 1990s by utilizing the state's own climate and soils that are suitable for sugarcane growth, developing new and more productive sugarcane varieties, implementing better infrastructure and transportation, and most importantly by introducing management practices that increase efficiency and productivity (Moreira and Goldemberg, 1999, Martinelli and Filoso, 2008).

As the sugarcane industry increased production efficiency, demand for sugarcane continued to rise. Higher international prices for sugar, stronger demand for sugar in Brazil, increased gas prices, and the introduction of the flex-fuel car in 2003 all encouraged the growth of the sugarcane ethanol industry (Rico et al., 2010; Nogueira and Capaz, 2013). Flex-fueled cars became extremely popular in Brazil, especially with the incentive of offering owners the option of using gasoline (with 20-25% anhydrous ethanol), hydrated ethanol, or any combination of the two depending on availability, price and performance (Wilkinson and Herrera 2010; Nogueira and Capaz, 2013). Currently 95% of all new car sales are flex-fueled, and approximately 50% of gasoline has now been replaced by ethanol (Goldemberg, 2013). In 2003 ethanol produced 15 billion liters of ethanol and by 2008/09 it produced 25 billion liters of ethanol (Wilkinson and Herrera, 2010). Petrobras, the national oil company of Brazil, believes that by 2020 the total Brazilian car fleet will be 75% flex-fuel, 17% petroleum, 1% full ethanol, and 7% diesel (Neves et al., 2011).

To meet these increased demands at home and abroad, sugarcane production needed to expand even further. This expansion started in São Paulo, where the sugarcane harvested area doubled from 1995 to 2012 (IBGE, 2012). By 2011, sugarcane already covered 21.7% of the entire state's surface (Adami et al., 2012). As sugarcane continued to expand throughout São Paulo, land prices became more competitive. In 1995 sugarcane industry paid R$175.01 a hectare per year, and by 2008 it had increased to R$502.19 a hectare per year (Novo et al., 2010). The rise in land prices was not the only increased cost in the sugarcane production for São Paulo; new environmental restrictions also played a part in the higher costs.

In 2002 the state of São Paulo established a major environmental and social law that moved to ban sugarcane burning (Martinelli and Filoso, 2008). Law 11,241 was created to deal with the health complications resulting from the pre-harvest burning of sugarcane for the large metropolitan regions of the state (Martinelli and Filoso, 2008; Sawyer, 2008). The Law 11,241 required that by 2006 only 30% of areas with less than 12% slope could be burned and that burning would be completely outlawed by 2021. In addition the industry leaders in São Paulo, pushed for sugarcane burning to be stopped completely within the state by 2014 (Martinelli and Filoso, 2008). To harvest sugarcane without the use of manual laborers, the industry needed to mechanize sugarcane harvesting. The mechanization of the sugarcane harvest allows for the sugarcane to be cut and transported without the dirty and strenuous manual harvesting, which requires burning to access the sugarcane stocks. Scholars using remote sensing techniques have studied São Paulo sugarcane burning over the past 15 years and have found decreases in sugarcane pre-harvest burning, despite the expansion of the crop (Rudorff et al., 2010; França et al., 2014). Therefore, new areas with relatively low slopes are ideal for sugarcane expansion.

Even with the increased expansion of sugarcane within the state of São Paulo, the industry could not meet the rising demand for ethanol at home and abroad. New regions with lower land prices, areas adequate for mechanization of sugarcane harvesting, and lands in close proximity to the state of São Paulo were needed to deal with the increased demand and cost of production. Due to these restrictions, the new regions perfectly suited for sugarcane expansion came from the Center–West region within the Brazilian Cerrado, and in particular in the states of Goiás and Mato Grosso do Sul.

2.3 The Influence of Foreign Direct Investments

Historically, the states of Goiás and Mato Grosso do Sul, located in the Brazilian Cerrado, have been characterized by rural populations and dominated by large cattle ranches (Ratter et al., 1997). That began to change from the middle of the 20th century with domestic and foreign investments into the Center–West. On the domestic side, the federal government was concerned with low population density of the Cerrado. Thus, in a geopolitical move by the Brazilian government, a new capital of Brazil (Brasilia) was constructed in what was then the state of Goiás. Also, to help feed its own domestic population and become an agricultural commodities exporter, investments into agricultural technologies, developed by Brazilian Agricultural Research Corporation (EMBRAPA) and subsidies from the government helped bring modern agriculture into the Cerrado (Rada, 2013). As a result, these infrastructure investments helped to connect the new agricultural lands to the southern regions of Brazil, and more important to the world market. Lower land prices, subsidized farm loans for equipment, and investments into agricultural technologies helped spread the modernization of agriculture, through large-economies of scale, which in turn produced massive monoculture farms (Muller, 1996; Kaimowitz and Smith 2001; Klink and Moreira 2002; Jepson, 2006; Brannstrom et al., 2008). One of the monoculture crops that flourished in the Cerrado was the soybean plant. These new soybean varieties that could withstand the harsh Cerrado climate and soils have changed the agricultural landscape of the country. In 1970 only 6.9% of the country's soybeans were grown in the Cerrado, but by 2006 that number was up to 60.4% (Pereira et al., 2012). The development of these agricultural technologies transformed the Center-West region of Brazil, which has become extremely important to Brazilian agriculture. Today this region accounts for large proportions of other important crops, such as corn (43.3%), cotton (98.1%), and coffee (49%) (Pereira et al 2012) and now sugarcane.

Different from other crops, the expansion of sugarcane required much more investment due to the difficulty of harvesting and processing of the crop. Once sugarcane is harvested, it quickly loses its sugar content, which is needed for both ethanol and sugar. Therefore, sugarcane mills must be located near sugarcane fields. Due to the large cost involved in financing a sugarcane mill, until 2005 only 22 mills were operational in Goiás and Mato Grosso do Sul. Attractive land prices, tax incentives, and now foreign capital helped finance the infrastructure needed to expand sugarcane.

With improved roads and a proposed construction of an ethanol pipeline from Petrobras, the national oil company of Brazil, to markets and ports in the south of Brazil, massive amounts of foreign investments have come to the sugarcane industry in the Cerrado. Rising oil prices, national security for Western nations, and concerns over global warming have increased foreign capital into the industry. Foreign Direct Investment (FDI) has increased and in particular helped expand sugarcane production by merging with domestic companies or buying them out completely (Neves et al., 2011). Three of the largest crushing capacity companies within Brazil all have foreign investment. Cosan, the largest producer within Brazil, signed a $12 billion dollar joint venture agreement with Shell in 2010; Santelisa Vale (SEV), another major producer in Brazil, became a joint venture with the French company of Louis Drefus Commodities (LDC) when they attained 60% equity stake in the company in 2009; Moema, another large producer in Brazil, was purchased by Bunge also in 2009 (Neves et al., 2011). The global financial crisis helped speed up the consolidations, which led foreign capital to seek these investments (Neves et al., 2011). With the support of FDI, 40 new mills have been constructed in Goiás and Mato Grosso do Sul from 2005 to 2013.

The increase in new mills helps to explain the large increase of area planted in sugarcane. In 2000 Goiás contained 139,000 ha of sugarcane, but by 2010 this area had increased to 573,000 ha (Valdes, 2011). Mato Grosso do Sul also saw an increase; in 2000 the state had 135,000 ha of sugarcane, but by 2010 it had increased to 222,000 (Valdes, 2011). It is important to note that this incredible expansion of sugarcane in a relatively short period of time has brought changes to the physical landscape of the region. However, at the same time that the importance of this crop increases, it also brings concerns over the industries' impact on the people of the Cerrado.

Foreign direct investment into the Brazilian sugarcane ethanol industry raises real concerns over socioeconomic problems associated with sugarcane production. There are many worrying accounts of poor working conditions for sugarcane harvesters (Wilkinson and Herrera, 2010; Ribeiro, 2013). Sugarcane crop requires large land holdings in order to be productive, thus increasing the concentration of land and wealth (Sawyer, 2008; Valdes, 2011). In addition, the mechanization of the harvesting process can displace 80 workers (Smeets et al., 2008). If on the one hand the mechanization of sugarcane harvest may displace workers, the industry also brings employment to the region. For every 300 million tons of sugarcane produced, around 700,000 jobs are created (Goldemberg et al., 2008). The addition of temporary jobs for construction of the mills can bring in unskilled and skilled laborers to eventually work in the mill (Ribeiro, 2013). Wages for the sugarcane ethanol sector are higher than the minimum wage and higher than the wages of many other sectors (Neves, 2010; Smeets et al., 2008).

The complexity of issues surrounding sugarcane industry's impacts on not just the economy, but also on development and environment requires further review. In order to understand these impacts, the next chapter will review the literature on the history of agricultural expansion into the Cerrado. Moreover, it will review how investments in agriculture both domestically and from foreign capital impact development in rural places. Finally, it will examine the socioeconomic, economic, and environmental impacts of sugarcane.

Chapter 3 - Literature Review

Land use and cover change of the Brazilian Cerrado has been much studied and large number of research has highlighted the importance of this region for the world's biodiversity. Despite the academic attention, a significant knowledge gaps still exist in the literature. In the context, this chapter aims to fill these gaps with a detailed literature review. This literature review will first describe the agricultural expansion into the Brazilian Cerrado. Next, it will summarize the impacts of agriculture and the environment in rural places. Third, it will review the diverse socioeconomic implications of sugarcane expansion. Fourth, it describes how economic investments impact agriculture and rural places. The next aim of this reviews the contested effects of Forging Direct Investment on economic growth. The conclusion of the literature review will describe how Foreign Direct Investments has impacted Brazilian agriculture.

3.1 Agricultural expansion into the Brazilian Cerrado

Human occupation of the Cerrado is not a modern phenomenon; archaeologists have found evidence of hunter-gatherer cultures in these savannas dating back to as early as 9,000 years ago (Klink and Moreira, 2002). The Portuguese were the first Europeans to discover the Cerrado during their search for gold, and they used the native populations as slave laborers (Encyclopedia Britannica, 2014). By the early eighteenth century permanent settlements started to appear near these gold mining areas (Klink and Moreira, 2002). Once these mines had expired, the settlers turned to agriculture. But, cattle ranches were also particularly attractive due to the large grasslands available throughout the Cerrado biome (McCreery, 2006). The first geopolitical move by the Brazilian government to settle the Cerrado came after the Paraguay War from 1864 to 1870. The Brazilian government offered incentives to settlers to grow tea along the southern border of Mato Grosso (Klink and Moreira, 2002).

The settlement of the Cerrado became more enticing during the early 1900s as fence wire prices decreased and construction of railroads connected settlers and their cattle to the rest of Brazil (McCreery, 2006). In addition, by the 1920s, coffee became very popular in the state of São Paulo, which displaced more cattle ranches into the Cerrado as coffee beans came to replace pastures (Klink and Moreira, 2002). Another settlement program supported by the Brazilian government throughout the 1930s used land, technical assistance, and subsidies to entice farmers to settle in southern Goiás (Klink and Moreira, 2002). Still, the Cerrado had low population density and was mostly occupied by large cattle ranches, but this began to change with a flood of investments into the Cerrado (Kaimowitz and Smith, 2001).

The region was transformed during the 1950s and 1960s with the construction of the new capital city of Brasilia, located in the heart of the Cerrado. This move was geopolitically motivated, aiming to open up the vast unoccupied core of the country for agriculture and development (Snyder, 1964). The construction of Brasilia brought a network of paved highways connecting it, and the Cerrado region in general, to more developed regions and markets of Brazil, allowing new lands to be opened up for occupation (Muller, 1996; Klink and Moreira, 2002). The paved road network in Brazil increased dramatically from 36,000 kilometers in 1960 to 190,000 in 2006 (Baer, 2001). However, the construction of Brasilia and the network of paved roads alone cannot fully explain the settlement of the Cerrado. As in other developing regions of the world, government agencies were also crucial towards developing and settling the Cerrado.

Although new roads could bring farmers to the Cerrado, the issue of financing the settlement of farmers and the mechanized farming machinery necessary for modern agriculture was still a roadblock to settlement in the region. One agency's financing was vital in opening the Cerrado, the Program for the Development of the Cerrado (POLOCENTRO), which was created in 1975. The main goals of POLOCENTRO were to expand and develop the agriculture of Cerrado, with the incentive to grow crops that were important for the global market (Wolford, 2008). In an effort to bring the Cerrado into the global market, POLOCENTRO selected 12 areas with strong agricultural potential. These areas held several basic requirements for functioning markets, including accessibility for transportation to reach the area and availability of unoccupied land (Muller, 2003). POLOCENTRO set out to improve infrastructure and develop new agricultural technologies in these areas (Muller, 1996; Klink and Moreira, 2002). Settlers both large and small utilized agricultural loans and or credit, but 75% of these production loans were given to only seven crop types: corn, soybeans, rice, wheat, coffee, maize and sugarcane (Klink and Moreira, 2002). In addition, POLOCENTRO distributed loans based on planted area, which benefited medium to large-scale farmers planting commodity crops more than small scale farmers growing food or subsistence crops (Klink and Moreira, 2002). These medium to large-scale farmers were additionally able to enjoy the subsidized credit, which allowed investment and production credit to be available at a low nominal interest rate. These low rates, combined with rising inflation and the program's long repayment period, basically made POLOCENTRO loans handouts (Muller, 1996; Klink and Moreira, 2002). From 1975 to 1982, 3,373 agricultural projects were approved, totaling to 577 million dollars, and 81% of farms were over 200 hectares and accounted for 88% of the total funds allocated (Klink and Moreira, 2002).

Despite POLOCENTRO's efforts to improve production by means of subsidies, credit and infrastructure were crucial, actually producing crops in the low fertile soils and tough climatic conditions of the Cerrado remained a challenge. The majority of soils in the Cerrado are oxisols that typically have low pH levels and high aluminum contents (Brannstrom et al., 2008; Ratter, 1997). The climate ranges from 18° to 28° C, and annual precipitation ranges from 800 to 1800 mm with the majority falling in the wet season, which is typically from October through March (Brannstrom et al., 2008). Given these challenges, in 1973 the Brazilian government started the Brazilian Institute for Agricultural Research (EMBRAPA). EMBRAPA performed its own research and coordinated with universities, farmer cooperatives, state-level research centers, and private companies to develop new crop varieties that would grow more easily in the Cerrado (Kaimowitz and Smith, 2001). EMBRAPA developed new varieties of soybeans and other crops that resulted in much higher yields than ever before (Kaimowitz and Smith, 2001). Researchers also developed other agricultural technologies to improve crops. They used the application of phosphate fertilizer and lime to correct nutrient deficiency and acidity, Rhizobium-based nitrogen fixation, and the heavy use of herbicides and pesticides and modern machinery (Kaimowitz and Smith, 2001; Klink and Moreira, 2002). These agricultural technologies gave medium and large farms an advantage due to the large economies of scale needed to produce soybeans competitively (Kaimowitz and Smith, 2001; Klink and Moreira, 2002).

As expected, government investments in the Cerrado, such as building new paved roads and developing programs for the settlement of farmers and agricultural technologies, were essential to stimulating the movement of people into the Cerrado. However, it was not just agriculture that increased; pastures planted with more productive but nonnative grasses have also increased in Cerrado, raising further concerns about losses in biodiversity (McAlpine et al., 2009). The development of agricultural technologies transformed the center of Brazil, and as a result the Cerrado has now become extremely important to Brazilian agriculture. Today this region accounts for large proportions of the country's crops, in addition, sugarcane has become one of the most important crops in the region. Sugarcane production in the whole of Brazil doubled from 2000 to 2011. Nevertheless, production in the center-west region of Brazil, where a large portion of the Cerrado is located, increased even more dramatically, from 24,481,317 tons in 2000 to 103,896,123 tons in 2011 (IBGE, 2012).

The exponential growth of sugarcane production in the center-west region of Brazil is the result of several factors. For instance, the center-west region of Brazil has a long dry season that sugarcane plants require in order to grow successfully (Brannstrom et al., 2008; Goldemberg et al., 2008; Miyake et al., 2012). In the state of São Paulo, which is the major sugarcane-growing region of the country, land prices increased about 114% from 2001 to 2006 (Goldemberg et al., 2008). In addition, new Brazilian laws went into effect restricting sugarcane expansion into lands with over 12% slope due to difficulties for mechanized harvesting (National Forestry Code and Environmental Crime's Law). The center-west region of Brazil became the perfect location for sugarcane expansion due to both its long dry season and its abundance of lands under 12% slope (Martinelli and Filoso, 2008). However, this expansion of sugarcane in the center-west may come at the expense of soybeans and cattle pastures, which may be indirectly displaced to other regions, such as the Amazon (Martinelli and Filoso, 2008; McAlpine et al., 2009; Novo et al., 2010; Adami et al., 2012). While this expansion of sugarcane may be displacing lands in the frontiers of Brazil, the expansion of sugarcane has already directly displaced crops and pastures in the state of São Paulo (Goldemberg et al., 2008; Adami et al., 2012). In 2007, two-thirds of the 654,000 hectares of land converted to sugarcane throughout all of Brazil were converted from pasture (Valdes, 2011). Since 2000, sugarcane in the state of São Paulo has expanded onto pastures by 69.7%, annual crops by 25%, and forest by 0.6% while 3.4% of sugarcane land was under crop rotation (Adami et al., 2012). Sugarcane expansion in the state of São Paulo has occurred predominately in pastures, however this may not be the case for the state of Goiás. According to data collected from IBGE in 2012, the amount of rice planted in Caçu and Quirinópolis located in the state of Goiás has greatly reduced, thus raising questions about food security in these areas.

The expansion of agriculture into the Brazilian Cerrado aimed to help feed the domestic population and become an agricultural commodity exporter for the world. Another aim was to help develop the vast center of the country into productive area. This aim has helped fuel the expansion of sugarcane into the Cerrado, bringing with it a new wave of development. However, the development brought by the sugarcane industry is a complicated issue due to both its positive and negative environmental, economic and socioeconomic impacts. The next section will help clarify the various impacts that sugarcane has on these complicated issues.

3.2 Sugarcane's Impact on Agriculture and the Environment in Rural Places

The expansion of sugarcane in the Cerrado has created a discussion about its positive and negative impacts on a variety of areas, ranging from the environment to both human and economic development.

Some scholars argue that sugarcane expansion into the Cerrado has deforests natural vegetation. These scholars also express concern that sugarcane has displaced soybean crops, corn crops, and planted pastures used for cattle production (Nassar et al., 2008; Rudorff et al., 2009; Adami et al., 2012; Novo et al., 2010; Pereira et al., 2012). Farmers and ranchers in southern Brazil, and in the state of São Paulo in particular, often sell or rent their land for sugarcane production and then buy more and cheaper land deeper into the Cerrado (Goldemberg et al., 2008; Miyake et al., 2008). This practice further increases land use land cover change by opening up frontier lands where farmers move their displaced pastures and crops into the native vegetation, which has many negative impacts for the environment (Sparovek et al., 2007). Although estimates vary, as much as 55% of the Cerrado's natural vegetation had been cleared by 2002. If current clearing rates continue the natural vegetation of the Cerrado will be gone by 2030 (Manchado et al., 2004). The World Wildlife Fund reported that by 2011 only 20% of the original Cerrado remained. This is alarming, especially since only 3% of the region is under legal protection. These facts loom over the extremely diverse plant and animal life for this biome. Countless animals such as the giant anteater, giant armadillo, Maned Wolf, and jaguars, as well as the 11,000 plant species that call the Cerrado home, are under the threat of the destruction of their natural habitat. In addition, 44% of these fauna and flora are endemic to the region (World Wildlife Fund, 2011). Although the Brazilian Forest Code legally requires landowners in the Cerrado to hold 35% of their lands for preservation, this law is not regulated very strictly, leaving a large amount of land in this area up to the whims of the landowners (Brazil 2009, World Wildlife Fund, 2011). Obeying and enforcing this law is vital because the extremely low amount of native Cerrado under government protection and how modern agriculture lends itself to large monoculture farms (Sawyer 2008, Nogueira and Capaz, 2013).

Sugarcane is one of these crops that tends to produce large monocultures that can reduce biodiversity, but sugarcane also can lead to soil degradation. Soil degradation is high in sugarcane fields due to management practices that leave the soil bare and exposed to tough rains and winds during conversion of the natural grasses before planting and after harvest (Azadi et al., 2012; Martinelli and Filoso 2008; Nogueira and Capaz, 2013). Additionally, soil compaction is an issue because of the increase of the use of heavy machinery due to the expansion of mechanization (Azadi et al., 2012). Although very little amounts of sugarcane are irrigated, during the sugarcane processing stage water is used to wash the sugarcane. This process creates a byproduct called vinasse (Goldemberg et al., 2008). When directly entered into the water supply, this byproduct increases the biochemical oxygen demand, which in turn dissolves waters and can cause anoxia (Martinelli and Filoso, 2008). Furthermore, if planted in low fertile soils, sugarcane crops require fertilizer in order to be productive. By 2006, 3.13 million tons of fertilizers were used throughout the country on sugarcane (Martinelli and Filoso, 2008). It is not possible for all nitrogen fertilizer to be absorbed into the fields and plants. This superfluous fertilizer is distributed into water bodies, causing eutrophication of coastal waters, much like those found in the Mississippi Delta that flows into the Gulf of Mexico (Martinelli and Filoso, 2008). The burning of sugarcane fields to help with manual harvesting also brings environmental detriments (Azadi et al., 2012). While some farms in Brazil are crossing over to mechanized harvesting, which does not require burning, a majority of 70% of sugarcane area was still burned in 2006 (Martinelli and Filoso, 2008). One of the consequences of burning is related to aerosol particles released that are damaging to human health, especially when they form to create acid rain (Martinelli and Filoso, 2008; Goldemberg et al., 2008). In addition, the burning of sugarcane releases gas emissions into the atmosphere, which further contribute to the greenhouse effect (Goldemberg et al., 2008). These various negative impacts caused by the increase of sugarcane production are alarming, but it is important to also understand the many positive effects that sugarcane production has brought to Brazil.

Sugarcane production results in many positive effects on the environment. Sugarcane ethanol has reduced CO2 emissions since 1975 by 600 million tons, or about 7% of Brazil's total CO2 emissions for energy consumption for the time period (Valdes, 2011). In addition, sugarcane biofuel reduced greenhouse gasses by 61% compared to gasoline (Valdes, 2011). Sugarcane ethanol is far more efficient that corn-based ethanol, producing 45% more ethanol across the same amount of land and having an energy yield ratio of four to six times greater (Crago et al., 2010; Valdes, 2011). Since 1976, Brazil has substituted 1.51 billion barrels of gasoline for ethanol, saving about $75 billion dollars (Goldemberg, 2013). By 2006, 44% of all energy used in highway transportation in Brazil came from ethanol (Leite et al., 2009). Furthermore, Brazilian sugarcane yields per hectare have increased by 33% since the year 2000 (Valdes, 2011).

The increase of sugarcane yields in Brazil has not only reduced the use of gasoline by replacing it with ethanol, but also has increased the amounts of bagasse, the byproduct of leftover sugarcane stocks, which now can be used to power sugarcane mills. Bagasse has even pumped energy back into the electrical grid during the peak season (Hofsetz and Silva, 2012). This peak season, during the dry season for south central part of Brazil, coincides with the lowest levels of hydro-electrical power. As a result, there is an increased interest in providing new technologies to increase sugarcane cogeneration electrical production (Hofsetz and Silva, 2012). From 1999 to 2013, bagasse production increased from about 86 million tons to 169 million tons (Hofsetz and Silva, 2012). Unfortunately, cheaper prices for other electrical products, such as coal, have limited the investment in this sector. Regardless of limited investment, the Brazilian Energy Plan estimates that by 2015, the potential for surplus electricity generation in the sugarcane production could reach 19.3 TWh and 44.TWh by 2030 (Hofsetz and Silva, 2012). Compared to other crops, sugarcane uses smaller amounts of pesticides and fungicides, and the organic byproduct vinasse and filter cakes are applied on the field as an organic fertilizer (Neves et al., 2011). Sugarcane also has considerably less soil loss than other crops due to the semi-perennial nature of the crop; sugarcane only needs to be planted once every five to six years (Valdes, 2011). Furthermore, as mechanization increases, sugarcane straw is left behind in the field, providing further soil cover and more organic matter to be recycled as seen in Figure 3.1 (Neves et al., 2011).

Figure 3.1 Mechanized harvesting of sugarcane (a) and a farmer shows sugarcane straw left behind after the mechanized harvesting (b) from fieldwork conducted July of 2014

Overall, the positive impacts of Brazil's sugarcane ethanol industry on the environment and agriculture seem to outweigh the negative impacts. The success of the industry has increased the popularity of ethanol and other biofuels worldwide as a means for countries and private industries to help national security concerns of oil supplies.

3.3 Socioeconomic implications of sugarcane expansion

Just as scholars have discussed the numerous pros and cons associated with the production of sugarcane on the environment and agriculture, equally debated are the socioeconomic issues involving this crop.

One major negative in the sugarcane industry is the working conditions for sugarcane harvesters. Workdays are typically eight to 12 hours long and involve the difficult labor of cutting and carrying sugarcane around the charred remains, which are harmful to the lungs

(Martinelli and Filoso, 2008). Sugarcane workers are paid by how many stocks they cut a day, and the workloads have risen dramatically over the past 30 years (Martinelli and Filoso, 2008). In 1970 the average worker cut three tons a day, but by 2010 this average had risen to 10 to 12 tons (Wilkinson and Herrera, 2010). These increased workloads have even proven to be fatal. For instance, in the state of São Paulo between 2004 and 2007, 18 harvesters were killed and half of those deaths were linked to high workloads combined with poor working conditions (Martinelli and Filoso, 2008; Goldemberg et al., 2008). Even more alarming are the cases of forced labor in the sugarcane industry (Azadi et al., 2012). One particular case of poor working conditions is in the Cerrado, in the state of Mato Grosso do Sul. Reports showed that the Brazilian Renewable Energy Company had unsafe and degraded living conditions for its workers, and used informal recruiting practices without a formal contract (Wilkinson and Herrera, 2010; Neves et al., 2011). The Brazilian Renewable Energy Company's famous local and foreign investors include former U.S. president Bill Clinton, former president of the World Bank James Wolfensohn, and former president of Petrobras Henri Reichstul. Another problem is the amount of land required to produce sugarcane. In other words, large-scale farms are needed in order to be productive and competitive, or economy of scale. The problem is, large-scale farm tend to concentrate land and wealth, leaving fewer opportunities for less wealthy farmers (Sawyer, 2008; Valdes, 2011). Therefore, by 2008, 75% of sugarcane producing land was owned by large producers (Goldemberg et al., 2008).

Nevertheless, some of the problems in the sugarcane industry are now starting to be addressed. As the sugarcane industry grows into a global commodity for both sugar and ethanol, concerns also have grown locally, nationally and globally for sustainable practices of sugarcane production for both the environment and people of Brazil (Goldemberg et al., 2008). For instance, the state of São Paulo has led the initiative toward sustainability by phasing out burning of sugarcane, eventually eradicating all burning of areas suitable for mechanization by 2021 and the sugarcane industry set its own voluntary measures to limit burning in these areas by 2014 (Galdos et al., 2013). Some of the driving factors that led to these measures were the need to improve air quality in the large metropolitan areas of São Paulo, the lack of manual labor, increased labor costs, and the growth in popularity of voluntary sustainable certifications (Goldemberg et al., 2008; Galdos et al., 2013). In addition, the creation of one job in this industry requires only $11,000, while the creation of jobs in the petrochemical and chemical industries cost 20 times higher and the rate of jobs per unit of energy produced by sugarcane ethanol is 152 times higher than in the oil business (Goldemberg et al., 2008).

In addition to the lower cost of job creation compared to other energy industries, the human development levels in municipalities that had sugarcane in the state of São Paulo tended to be higher. (Martinelli et al., 2011). Using a combination of indexes that measure human development by wealth, employment and revenues, health, longevity, and education levels, Martinelli (2011) found that municipalities that had ethanol mills had higher human development levels and that municipalities with high concentrations of sugarcane but no ethanol mills also had higher human development levels than areas without. However, the authors indicate that if environmental damages were to be incorporated into the cost of sugar production the benefits would decrease (Martinelli et al., 2011). Furthermore, other reports show that child labor has decreased throughout the industry, wages have improved, and benefits for work and schools have increased (Balsadi, 2007; Wilkinson and Herrera, 2010).

While the impacts sugarcane has on the people of Brazil and the state of São Paulo are contested, the impacts of investments into agriculture are clearer. Most scholars agree that investing into agriculture in rural areas is good a way to address rural poverty (Lui, 2013; Tarique, 2008; Bhatia, 1999).

3.4 Economic investments implications on agriculture and rural places

Scholars overwhelmingly support the idea that providing investments in infrastructure into agriculture and rural areas encourages and increases development. Infrastructure in general is defined as all activities and facilities that assist to bolster expansion in production and income generation in the rest of the economy, rather than only in the infrastructure programs (Bhatia, 1999). Infrastructure in rural areas is generally tied with agriculture, where investments in roads, power supplies, and communications help bolster and grow the rural economy (Ashley and Maxwell, 2001). These infrastructure projects help rural areas create new jobs both on and off the farm and bolster incomes which directly leads to more local tax revenue. This tax revenue is often used to increase education investments and maintain and improve existing infrastructure that directly leads to improved welfare for the community (Ashley and Maxwell, 2001). Furthermore, the increase in rural infrastructure spending provides communities with important occupations like rural health workers, agricultural extension workers, and agricultural researchers are all significant to the growth of the agricultural economy in rural areas (Bhatia, 1999). Infrastructure development in rural areas also helps alleviate poverty and results in high economic rates of return of investments (Tarique, 2008). The World Food Summit in 1996 stated, “Roads, electricity supplies, telecommunication, and other infrastructure services are limited in rural areas, although they are of key importance to stimulate agricultural investment and growth” (Tarique, 2008). Tarique further emphasizes that infrastructure is essential to increasing famers’ access to input and output markets, to stimulating the rural non-farm economy and revitalizing rural towns, to increasing consumer demand in rural areas and to facilitating the integration of rural areas into national and international economies.

According to the Food and Agriculture Organization, investments in agriculture are the most important and effective way to reduce poverty in rural areas. These investments raise productivity and incomes for farmers, develop goods at lower prices, and create new employment opportunities (Lui, 2013). Unfortunately, domestic public sector investments in agricultural development, which are key for successful agricultural development, have fallen 7% over the past few decades, due in part to the debt crisis, where governments and private capital in developing regions of the world (Noorbakhsh et al., 2001; Hallam, 2009). However, this decline does open the door for private domestic and foreign investments into the sector. Although private sector domestic investments are still the biggest type of investment in agriculture throughout the world, foreign investments are growing. The FAO in 2013 found that global foreign direct investments (FDI) in the agro-food sector almost doubled from 2000-2005 and 2006-2008.

This recent expansion of FDI in the agricultural sector stems in part from the commodity price rise in 2007-2008 that led countries that are dependent on food imports to invest in developing countries where land, water, and other resources are more bountiful (Lui, 2013). One of the most targeted regions in the world for FDI in agriculture, due to its abundant resources and land, is the continent of Africa (Lui, 2013). Although the oil rich Middle Eastern countries and China have recently received the most attention for their agricultural investments into Africa, it is European firms that account for around 40% of all land acquired in Africa. Additionally 13% of investments come from North American companies, who are leading the race for developing biofuel production (Lui, 2013). This new form of FDI in developing countries is export driven, where the majority of lands are being produced for row crops, which require more mechanized technologies (Lui, 2013).

3.5 Effects of Foreign Direct Investment on Economic Growth

The debate on whether or not foreign direct investments (FDI) have a positive influence on host countries' economic development and growth is multifaceted. Some scholars argue that Foreign Direct Investments (FDI) through multinational corporations are the main vehicle towards channeling advances in technology to many developing countries (Borensztein et al., 1998; Noorbakhsh et al., 2001; Makki and Somwaru, 2004). This technological diffusion, whether in the imports of high-technology products, adoption of foreign technology, or investment in education or skills, is vital towards economic development (Borensztein et al., 1998). Interestingly, the impacts of FDI on growth comes as the result of higher efficiency, and not just from more capital accumulation (Borensztein et al., 1998). Borensztein et al. (1998) and Makki & Somwaru (2004) cross-examined more than 60 developing countries over two and three decades and found that FDI plays a bigger role in the transfer of technology and the contribution of growth than domestic investment. The impacts of FDI are even greater for economic growth if the host country adopts and promotes citizens' ability to receive education (Borensztein et al., 1998; Makki and Somwaru, 2004; Zhang, 2001). They also found a strong positive interaction between FDI and trade, and determined that FDI stimulates domestic investments (Makki and Somwaru, 2004).

Other scholars also found that FDI have positive impacts to host countries' economies. Firebaugh (1992) examined the FDI already in the host country, as well as inward flows of FDI, and found that foreign investments did in fact foster economic growth, although not as strongly as domestic investment. De Soysa and Oneal (1999) looked at the effects of foreign and domestic capital on economic growth by replicating Firebaugh's (1992) study, but they also incorporated human capital into the analysis. According to De Soysa and Oneal (1999), it is important to understand how each country different social capacities enables it to absorb technologies, and how this may be factored into where foreign investments occur. Using data from the United Nations, De Soysa and Oneal (1999) also found that foreign capital is 2.7 times more productive than domestic investment, assuming that the mean value of human capital stays the same. In addition, they found that foreign capital productivity could increase by 2.5 if human capital increases by one standard deviation from the mean thus contradicting Firebaugh's (1992) findings (De Soysa and Oneal, 1999). De Soysa & Oneal's (1999) other findings included that FDI increases domestic investments, that increases in domestic investments increase FDI, and they found no evidence that foreign capital penetration has a negative effect on economic growth. Noorbakhsh et al. (2001) also found that human capital was extremely important for FDI inflows. Noorbakhsh et al. (2001) explains that human capital may impact the geographical distribution of FDI. This study shows that human capital was significant in determining FDI inflows. Human capital tended to be one of the most important factors towards FDI, and as human capital grew, investments also increased with time.

A related study by Alderson & Nielsen (1999) analyzed the relationship between income inequality and foreign capital penetration over 88 countries between 1967 and 1994 using cross-national data. Using the Gini coefficient of inequality and replicating the works of Firebaugh 1992, the study found that relative dependence on FDI is associated with greater inequality within the host countries.

FDI has also been shown to have no impact on output growth, but that it has positive effects in other areas (Azman-Saini, 2010). Azman-Saimi (2010) examined 85 countries over the

1975-2004 time period and found that higher levels of economic freedom in host countries' markets allow for greater absorption capacities of FDI. Azman-Saini (2010) also showed that counties that had higher levels of economic freedom had greater economic performance. Institutions within host countries had impacts on security of property rights, levels of corruption, and distortion, or extractive policies that affected whether or not there was incentive to invest in human and physical capitals (Azman-Saini, 2010). This report along with Noorbakhsh et al. (2001) helps explain that countries with higher human development levels tend to attract and maintain more FDI.

While there is evidence of numerous positive impacts of FDI on host countries' economies, some scholars have cast doubts on FDI's ability to help the host countries economy achieve growth. Kentor and Boswell (2003) show that when foreign investment in a country is strongly concentrated, it has a long-term negative effect on growth in GNP per capita using a series of panel regression models. Their models included a dependent variable of growth in GDP in five-year intervals from 1970 to 1995. Independent variables included foreign investment concentration, foreign capital penetration, export commodity concentration, export partner concentration, gross domestic investment, gross domestic product, secondary school enrollment, gross national product per capita and trade/GDP. The results found that high concentrations of foreign investment have a strong negative effect on GDP growth. This foreign investment concentration and penetration allows foreign investors to gain control over economic and political processes in the host country. Concentration leads to lack of autonomy and negatively affects the bargaining power of the countries in dealing with multinational corporations (Kentor and Boswell, 2003).

Furthermore, Carkovic and Levine (2002) examined the relationship between economic growth and FDI using both the World Banks data set and the International Monetary Fund from 1960-1995. Using econometric techniques that account for biases, the authors found that FDI does not support strong positive influence on economic growth. Carkovic and Levine (2002) state that the FDI influences on economic growth differentiates between national income, school attainment, domestic financial development and openness to international trade. A similar study performed by Herzer et al. (2006) also found FDI had no direct influence to short or long-term economic growth in the 28 developing countries studied in a cross-country analysis.

In addition, Curwin and Mahutga's (2014) case study focused on the impact that FDI has had on economic growth in Central, Eastern and Eurasian countries after the fall of the Soviet Union. Prior to the fall of the Soviet Union, the 25 countries in this study had little to no FDI in their economies, in addition to high levels of industrialization. These high levels were due to socialist policies which ended after the fall, making these countries the perfect laboratory for real time study of the FDI impacts on economic growth. The authors examined how FDI penetration (measured by the accumulation of inward FDI stock as a % of GDP) and FDI rate (measured by inward FDI flowed divided by FDI stock) impacted economic growth with controls for domestic investment. Domestic investment had a strong positive influence on economic growth during the time period of 1990 to 2010. These results offered a different explanation than many prior studies. Curwin and Mahutga (2014) found that more FDI penetration makes for less economic growth and that domestic investment is better than economic growth. The authors also argue that if FDI penetration happens rapidly, then economic contraction can also occur.

Looking at the case of Brazil, it can be argued that it to went through a government transformation during the 1980s and 1990s, much like the countries in Curwin and Mahutga's

(2014) study, which led to an increase in FDI. Nazmi (1998) examining the impacts of foreign capital on the Brazilian economy argue that Brazilian government viewed FDI as an inevitable product in dealing with the globalization of their economy during the early 1990s. As public sector downsized and privatization stepped in, foreign capital could potentially reap the rewards in the fast growing Latin American markets. FDI in Brazil had grown exponentially, from $184 million in 1989 to $9.6 billion in 1996, and FDI stock had grown to $96.2 billion by 1997, as new industries opened up to the global market (Nazmi, 1998). The author describes how joint ventures are common with transnational firms and local Brazilian companies, which is often seen today in the sugarcane industry. Finally, Nazmi, (1998) found that foreign investment actually crowds in domestic investment by means of a Brazilian law that requires financial institutions to reserve 60% of their funds to local investors and increases in joint venture projects. Although the majority of FDI that enters Brazil goes into the service sector, nearly $35 billion was invested in the agriculture sector by 2009, ranking third in the world (Lui, 2013).

3.6 Foreign Direct Investments impacts on Brazilian agriculture

As Brazil's economy started to open up to the world market in the late 1980s and early 1990s, the inward flow of FDI increased dramatically. In 1996 roughly 6% of all incoming FDI was related to agriculture or cattle ranching, and by 2006 this number had grown to 16%, or roughly US $3.5 billion (Neves et al., 2011). The fastest growing areas of sugarcane expansion are in the new frontier of the Cerrado, located primarily in the states of Goiás, Mato Grosso do Sul, and Minas Gerais, where a considerable amount of foreign investments are taking place (Neves et al., 2011).

Nascimento (2011) explains extensively how policies, legislation, and institutions impact foreign investments into Brazilian agriculture. These government actions are critical towards attracting investors who are concerned about these actions impacts on profitability and future investments. Nascimento (2011) found that as of 2009 Brazil had over US $372 billion in foreign direct stock throughout the entire economy with almost 35 billion invested in agricultural related activities. It is important to note that FDI is increasingly dominated by large Trans National Corporations (TNCs). These TNCs influence Brazilian agriculture immensely. All but four of the top 25 largest agricultural corporations in the world operate within Brazil (Nascimento, 2011). Increases in FDI since the 1990s have led large TNCs to outcompete small and medium domestic competitors. In fact, large TNCs increased their market share to 30% by 2000 (Chaddad and Jank, 2006). Foreign capital was responsible for 12% of all sugarcane crushed in Brazil in the 2004/2005 season, by 2010 this share had grown to 27% from companies such as Cargill, Shell, Bunge, and Louis Dreyfus Commodities (Neves et al., 2011). These TNCs also are increasingly involved in every level of the value chain supplying farmers with agricultural inputs, machinery, and infrastructures for different commodities (Chaddad and Jank, 2006).

FDI impacts can be classified into three different groups: economic, environmental, and social. FDI brings capital, but it also brings technologies for production and management skills to fit with local populations (Nascimento, 2011). Some of FDI, by means of TNCs, have conducted local research and/or partnered with Brazilian universities to help with the adaption and development of new technologies. One of the institutions that worked with TNCs was the Brazilian Agricultural Research Company (EMBRAPA), which was vital for development of technologies that made agriculture and rural development possible in the Cerrado and improved food and nutritional security for all Brazilians (Nascimento, 2011). The positive impacts of FDI involvement in the sugarcane industry include companies preserving natural forested areas and regulations on buying soybeans from recently deforested areas[1] (Nascimento, 2011). If on the one hand the impacts of FDI are clear and positive, on the other hand the environmental effects of FDI vary, ranging from loss in biodiversity and land change to pollution from agrochemicals (Nascimento, 2011).

[1] Brazil's Soy Moratorium is an international agreement to not purchase soybeans on lands deforested after July 2006 in the Brazilian Amazon.

Chapter 4 - Research and Sample Design, Study Area, and Data Collection

The central goal of this study is to understand how the structural organization of the sugarcane mills impacts development at a municipality level in the state of Goiás, Brazil. This goal will be address in two ways: First, by using field work completed by Kansas State University and funded by the National Science Foundation grant "Collaborative Research: Direct and Indirect Drivers of Land Cover Change in the Brazilian Cerrado: The Role of Public Policy, Markets Forces, and Sugarcane Expansion". Second, by using Brazilian census data to compare how domestic owned mills, foreign owned mills, and jointly owned mills affect socioeconomic development on the municipalities. In addition, this thesis uses remote sensing techniques to evaluate the influence that the sugarcane mills have on land use land cover change in these municipalities. This section will describe the study area of the Brazilian Cerrado and the justification for selecting the municipalities within Goiás. The following section will describe the data collection process during the fieldwork. The final section will describe the sample and the research design.

4.1 Study Area

The goal of this section is to describe the detailed characteristics of the Brazilian Cerrado and the state of Goiás. In addition, this section will explain the justification for the selection of the three municipalities within Goiás: Caçu, Edéia, and Quirinópolis.

4.1.1 Characteristics of the Brazilian Cerrado

The Brazilian savanna, known as the Cerrado, covers around 2 million km^2 of central Brazil and spans from 24° S to 4°S latitudes, roughly encompassing the edges of the Amazon forest to the Atlantic forest along the most southern states of São Paulo and Paraná as represented in Figure 4.1 (Ratter et al., 1997; Jepson, 2005). The climate of the Cerrado is tropical with an average temperature ranging from 18° to 28° C and annual precipitation ranging from 800 to 1800 mm with the majority falling in the wet season, typically from October through March, followed by the dry season from April through September (Brannstrom et al., 2008). The majority of soils in the Cerrado are oxisols that typically have low pH levels and a high aluminum content (Brannstrom et al., 2008; Ratter, 1997). The elevation range varies from 300 to 1800 m and the Cerrado also contains headwaters for many tributaries to the Amazon, Paraná-Paraguay and São Francisco rivers (Jepson, 2005).

The word "*cerrado*" is derived from the Portuguese term for "half-closed," or "dense" (Oliveira-Filho and Ratter, 2002). This describes the vegetation cover, which varies greatly in form from dense grasslands with some small shrub and tree cover to almost closed forest canopy of a height of 12 to 15 m, depending on soil fertility and groundwater regime (Ratter et al., 1997; Oliveira-Filho and Ratter, 2002). There are two major hypotheses to explain the origin of this savanna biome. One hypothesis is that the vegetation adapted to human occupation starting as early at 9,000 years ago by the occurrence of fire-adapted species (Ledru, 2002). The other hypothesis is that the Cerrado vegetation is naturally occurring. This idea is supported by fossil evidence of large mammal species living in the region at the end of the Pleistocene (Klink and Moreira 2002; Ledru, 2002). Whatever the origins of the Cerrado, the variation in its vegetation cover explains how it is able to host an estimated 160,000 species of plants, mammals, fungi and diverse flora, a biodiversity hotspot (Myers et al., 2000; Jepson, 2005).

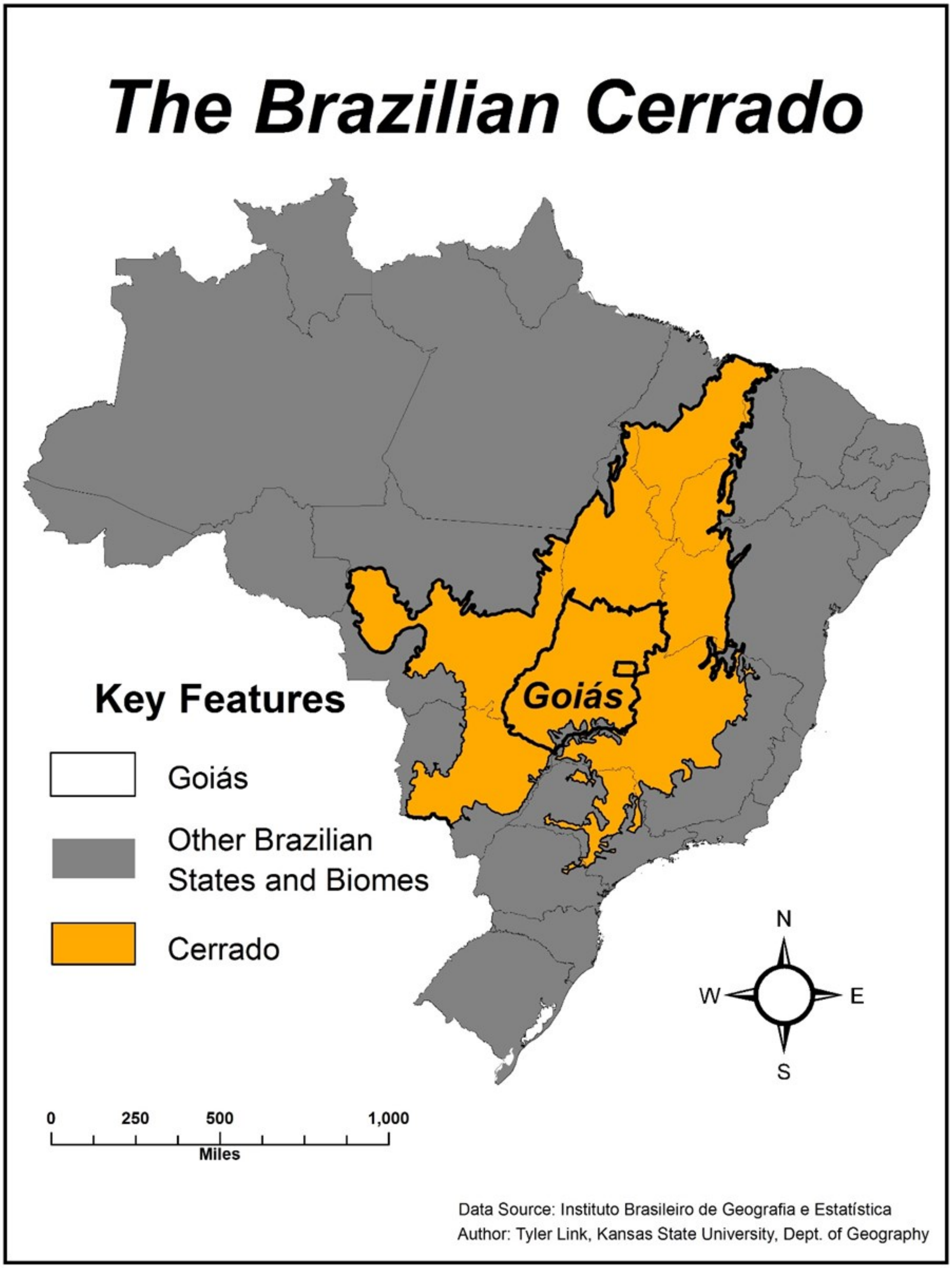

Figure 4.1 map of the Brazilian Cerrado

4.1.2 History and Characteristics of the state of Goiás

The Cerrado encompasses 11 Brazilian states and is the second largest biome in the country only behind the Amazon (IBGE, 2012). The state of Goiás is located in the Center-West region of Brazil and in the heart of the Cerrado as seen in Figure 4.2. Goiás has an area of 340,111 km², which is divided up into 246 municipalities and a population of just over 6 million (IBGE, 2014).

The settlement of Goiás did not happen overnight; the first European exploration and settlement into this state dates to 1682 when explorer Bartolomeu Bueno da Silva ventured up a tributary of the Araguaia River in search of gold (Encyclopedia Britannica, 2014). Goiás remained a frontier region over the next two centuries, eventually becoming a captaincy general in 1822, which was the same year that Brazil won its independence from Portugal (IBGE, 2014). Another seventy years passed before Goiás officially became a state in 1889. One of the first major settlement programs for Goiás supported by Brazilian government came during the 1930s. The Brazilian government supported colonization efforts in southern Goiás by luring settlers with land, technical assistance, and subsidies to entice farmers to move to the region (Klink and Moreira, 2002). One of the most transformational events for the state of Goiás was the construction of Brasilia during the 1950s and 1960s. The location for Brasilia was geopolitically motivated; the government hoped to open up the vast unoccupied core of the country for agriculture and development (Snyder, 1964). The construction of Brasilia brought a network of paved highways connecting Goiás to more developed regions and markets of Brazil and the world, thus allowing new lands to be opened up for occupation (Muller, 1996; Klink and Moreira, 2002). In the 1970s, government agencies such as the Program for the Development of the Cerrado (POLOCENTRO), and Brazilian Institute for Agricultural Research (EMBRAPA), made farming possible in the Cerrado's tough climate and soils.

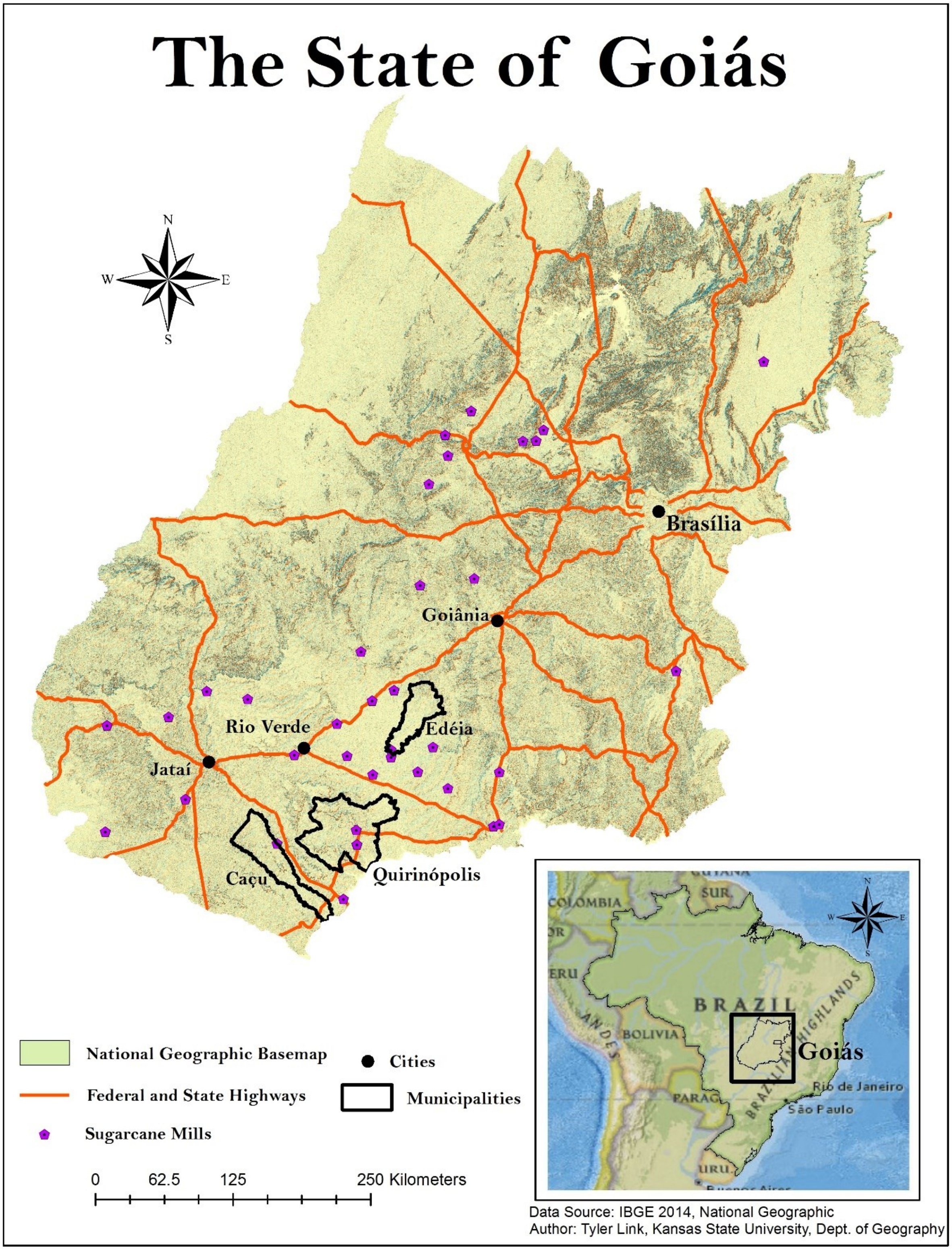

Figure 4.2 the state of Goiás

The influx of new investments into the capital helped transform the state of Goiás into a major economic and agricultural power in Brazil. Agriculture played an important part of Goiás's economy throughout its history, and agricultural investments greatly increased its importance to Brazil and the world economy. In 1970, the state agricultural GDP for Goiás was $1.5 billion, and by 2009 it had increased to $5.1 billion[2] (IPEA, 2013). This growth can be attributed to cattle and the introduction of monoculture crops. Goiás has historically been a cattle ranching state, and since development projects targeted the region, cattle numbers have increased. In 1974, Goiás had 8,970,253 head of cattle and by 2011 this number had increased to 21,744,650 head, averaging to over three cows per Goiás resident (IBGE, 2012). Although cattle numbers have grown, the greatest increase has been in the monoculture crops that were introduced at large scales during the 1970s. In 1970, Goiás land accounted for less than 1% of the Brazil's soybean and sugarcane production, and 4.29% of its corn (IBGE, 2012). By 2011, Goiás land accounted for 10.3% of Brazil's soybean production, 7.27% of its sugarcane production, and 10.32% of its corn production (IBGE, 2012).

The development policies have also impacted the nonagricultural economy of the state. Other economic activities also boomed due to the increased amounts of resources and infrastructure built throughout the last quarter of the 20th century. The industrial sector state GDP in 1970 was $399 million, but by 2009 it had grown immensely to $9.86 billion (IPEA, 2013). The most growth came from the service sector, which boosted its state's GDP from $2.43 billion to $21.5 billion from 1970 to 2009 (IPEA, 2013).

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[2] The state GDP was obtained using added value for basic prices US $, constant prices of 2000. Data was used from Brazilian Institute of Geography and Statistics (IBGE) and calculated by The Institute for Applied Economic Research (IPEA).

This boom in industry may have some relationship to the introduction of sugarcane to Goiás. Over the past 20 years, Goiás has dramatically increased its sugarcane production. Since 2005 over 22 new sugarcane ethanol mills have started operations in the state. From 1995 to 2011 production grew from 7,690,407 metric tons to 54,903,085 metric tons (IBGE, 2012). This increase produced jobs for constructing the mills, to run the mills, and spillovers into the local economies. One of this thesis' main objectives is to analyze if these investments vary by the ownership structure of the sugarcane mills.

4.1.3 The Selected Municipalities

The main objectives of this thesis are to compare and contrast the socioeconomic development and land use land cover change between three municipalities within the state of Goiás. We used several important criteria to select these three municipalities. First and foremost of the criteria was to select one municipality for each type of sugarcane mill ownership structures. The second requirement was to select municipalities that had similar area and populations. The third was to select municipalities that had sugarcane mills that became operational around the same time. In this context, the timing of the sugarcane mills was important in two ways. First it is important to see if sugarcane expansion over different crop or vegetation covers varied by the ownership structure of the mill. Second, to see if the investments in sugarcane mills impacted the socioeconomic development differently by ownership type.

The information in the catalog of Anuário da Cana 2013 (Brazilian Sugar and Ethanol Guide) was essential in order to select the municipalities with sugarcane mills. The 19th edition of the Brazilian Sugar and Ethanol Guide, developed by ProCana Brasil, gives detailed milling numbers, ethanol production, lists of board members, management of plants, information on the main varieties of sugarcane planted, and ranking of anhydrous ethanol and sugar production.

Population and area size of the municipalities were also considered, using the Brazilian Institute of Geography and Statistics (IBGE). Using both data sources, three municipalities emerged as the best choices for my research. The municipality of Caçu, which has a domestically owned sugarcane mill operated by the Brazilian company of Odebrecht was the first choice. The second selection was Edéia, which has an international sugarcane mill owned by British Petroleum. The third selection was the municipality of Quirinópolis, which was selected for its jointly-owned sugarcane mill, with the international company Cargill owning 50% and the domestic company USJ Group owning the remaining 50% creating SJC Bioenergy.

All three municipalities met the first criteria for the selection. One limitation for this thesis was Quirinópolis, which was the only municipality that had a jointly-owned sugarcane mill that became operational within the three year time period of the other two municipalities. Quirinópolis also had a larger area and population than the other two municipalities. In addition, Quirinópolis also had an additional sugarcane mill, Nova Fronteira S.A. that was opened a year after SJC Bioenergy by a joint venture between the domestic company São Martinho Group and the national oil company of Brazil, Petrobras Biocombustível. Nevertheless, due to Quirinópolis being the only jointly-owned mill that became operational within three years of the other two municipalities, it was selected for the research. An additional limitation for this study was a lack of a control group, meaning there was not a municipality that did not have a sugarcane mill, but fortunately it does not affect the outcome for this research.

4.1.4 The Municipality of Caçu

Peter Paula Smith family was the first to settle along the banks of the Rio Claro in the municipality of Caçu in 1858. (IBGE, 2015). It was not until the establishment of a Catholic church by a priest named Brom in 1920 that the village of Água Fria began to develop (IBGE, 2015). By 1924, Água Fria village became formally known as Caçu, and by 1954 Caçu officially became its own municipality, separating itself from Jataí municipality (IBGE, 2015). Located in the southwestern part of Goiás as seen in Figure 4.3, Caçu encompasses an area of 2,257.8 km² (IBGE 2015). The latest census calculated that the population of the municipality of Caçu was 13,283 people in 2010 and an estimated 14,603 people in 2014, with an urban population of 80.8% (IBGE 2010).

The economy of the Caçu originally focused on agriculture. In 1970 Caçu's GDP had $3,596,350 in its agricultural sector, $3,565,890 in its service sector, and $1,020,870 in its industrial sector. By 2010, the Caçu economy had grown in all sectors, but the main share of its GDP started to shift towards the service sector. The service sector now accounted for $36,398,960 of Caçu's GDP with agriculture sector accounting for $28,008,600 (IPEA 2013). The industry sector grew quickly after the arrival of the sugarcane mill. In 2007, two years prior to the start of operations in Caçu, the industry sector GDP of Caçu was $6.569,870. Three years later Caçu's industrial sector GDP had almost doubled to $12,310,830 (IPEA 2013).

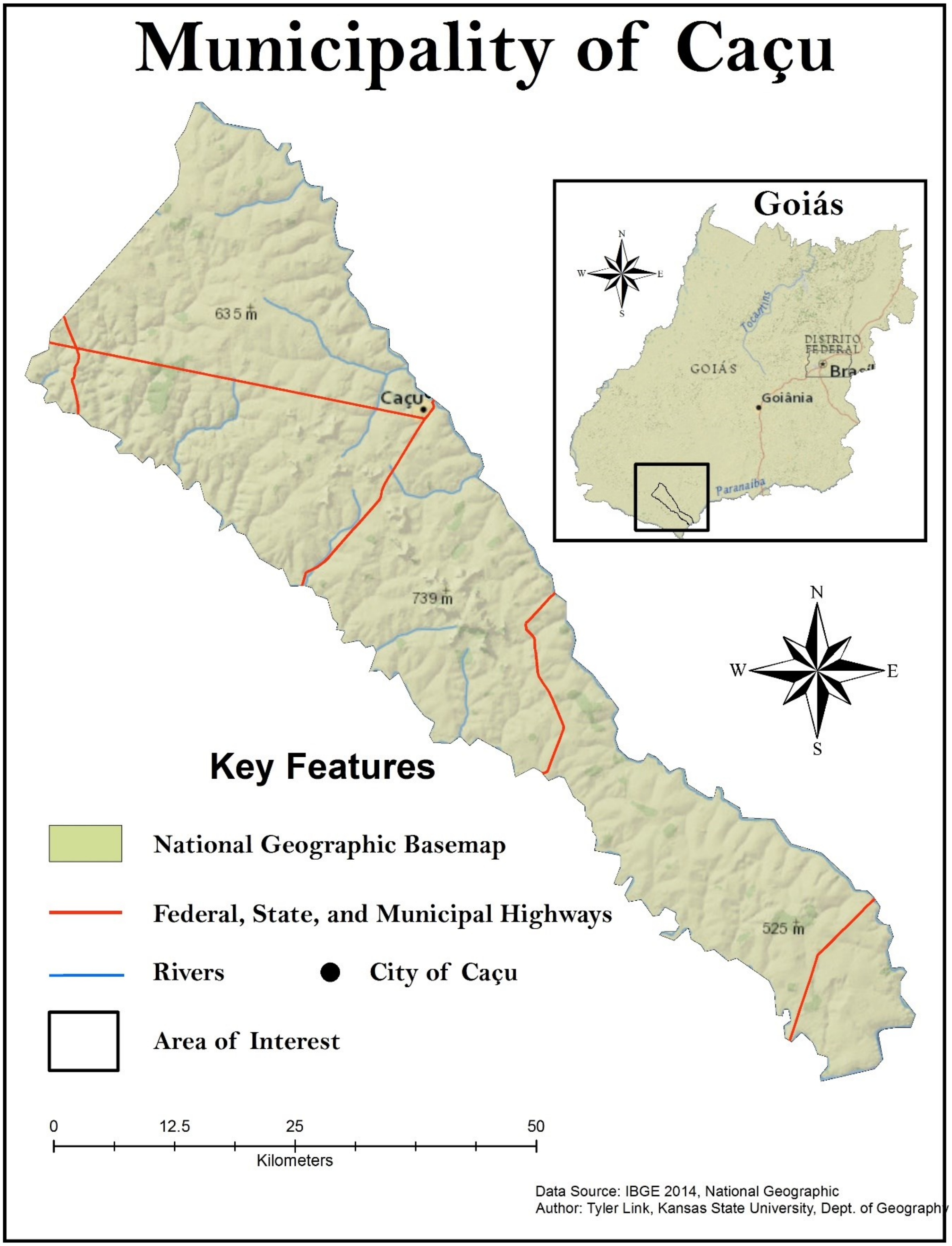


Figure 4.3 the municipality of Caçu

4.1.5 The Municipality of Edéia

The municipality of Edéia was originally settled by Cândido Martins da Rocha, Leandro Martins dos Anjos, and José Alves de Faria in 1913 along two rivers: Rio dos Bois and Rio Turvo (IBGE, 2015). These settlers named the village "Santo Antônio do Alegrete", but they eventually changed the name to Alegrete (IBGE, 2015). By 1915, the first business and a dentist had settled in the village and the population continued to grow (IBGE, 2015). The town's name was eventually changed once again in 1938 to Edéia, for reasons unknown. Edéia became a city in 1948 and a municipality in 1949. Located in the central-south part of the state of Goiás as seen in Figure 4.4, Edéia has an area of 1,466.3 km². The latest census calculated that the population of the municipality of Edéia was 11,266 people in 2010 and estimated population of 11,952 in 2014. The urban population of the municipality is 84.5% (IBGE, 2010).

The agriculture sector has the largest GDP value for Edéia. It grew from $6,857,140 in 1970 to $54,777,270 in 2010. Like Caçu, the second most important industry in Edéia is the service sector, which grew from $4,158,120 in 1970 to $43,647,880 in 2010. The most interesting sector to look at is the industrial sector, which, in 2006, had a GDP of $4,119,260. Amazingly, by 2010 the GDP had grown exponentially to $29,010,720 (IPEA, 2013).

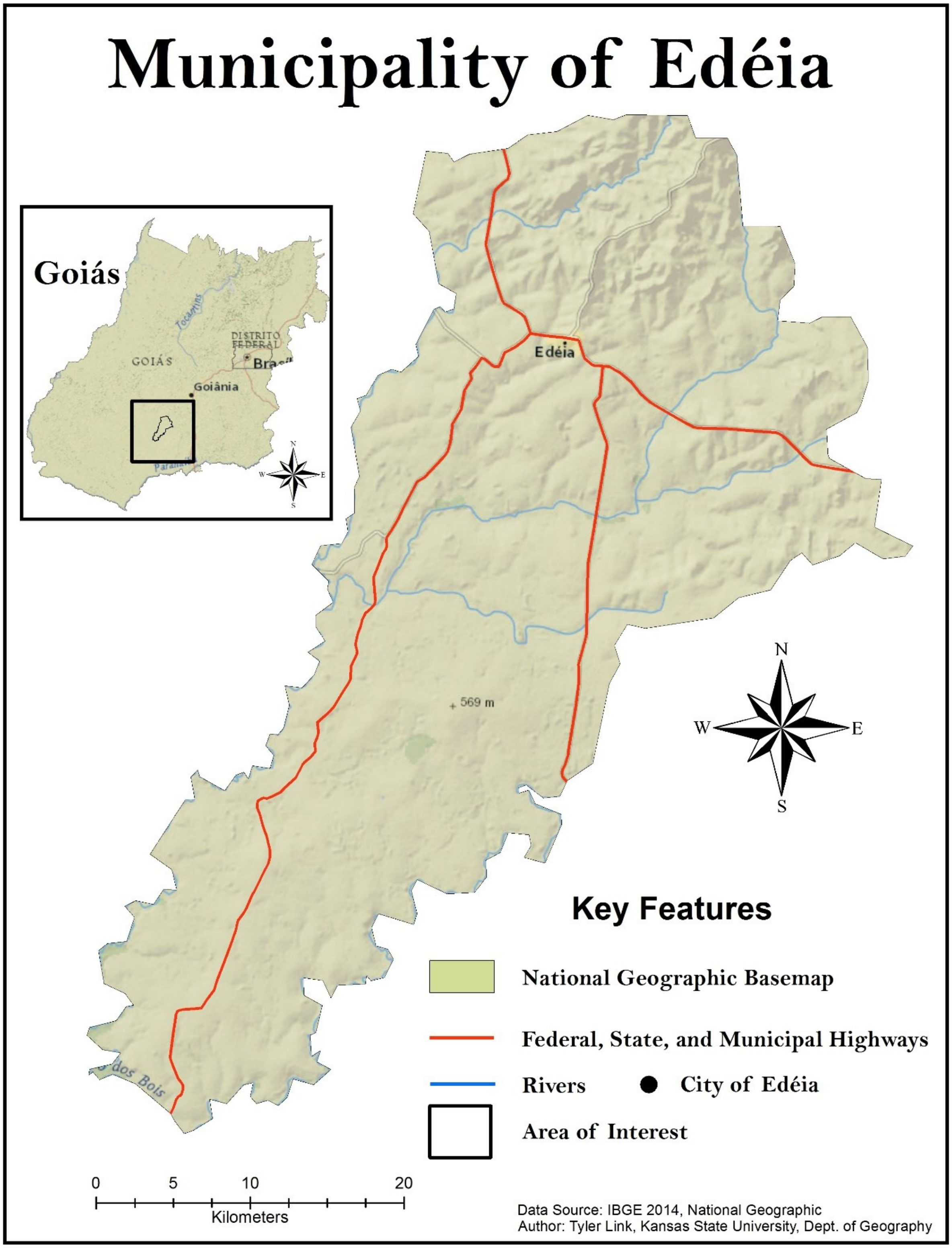


Figure 4.4 the municipality of Edéia

4.1.6 The Municipality of Quirinópolis

During the 1860s the provincial governor of Goiás, Luiz Gonzaga de Camargo Fleury, allowed for cattle and horse farms to be tax free for the first 10 years of operations. He hoped this would attract settlers from the more populated states of Minas Gerais and São Paulo. (IBGE, 2015). Eight years later, the city of Quirinópolis was founded (1868), with the establishment of a church and a business by Colonel Antônio Rodrigues Pereira (IBGE, 2015). The city and municipality gets its name from founder Colonel José Quirino Cardoso, who was instrumental to the colonization of the area and was an influential leader (Ribeiro, 2012). Quirinópolis was officially made a municipality in 1943 (IBGE, 2015). Located in the south of the state of Goiás as seen in Figure 4.5, Quirinópolis has an area of 3,780.2 km². The latest census calculated that the population of the municipality of Quirinópolis was 46,788 people in 2010, with an urban population of 88.3% (IBGE, 2010).

The economy of Quirinópolis has changed since the 1970s. Once dominated primarily by agriculture, it has now diversified and become an important industrial hub for southern Goiás. Agriculture has also grown during this time period. The GPD of the municipality grew from $34,202,200 to $79,471,137 in 2010. The service industry has grown significantly as well, from $18,421,450 of the municipality's GDP to $143,036,760 by 2010. Much like the previous two municipalities, the industrial sector grew tremendously after the introduction of the sugarcane mill. In 2005, two years prior to the mill's opening, the industrial sector GDP accounted for $28,176,130, and it grew to $92,509,020 by 2010 (IPEA, 2013).

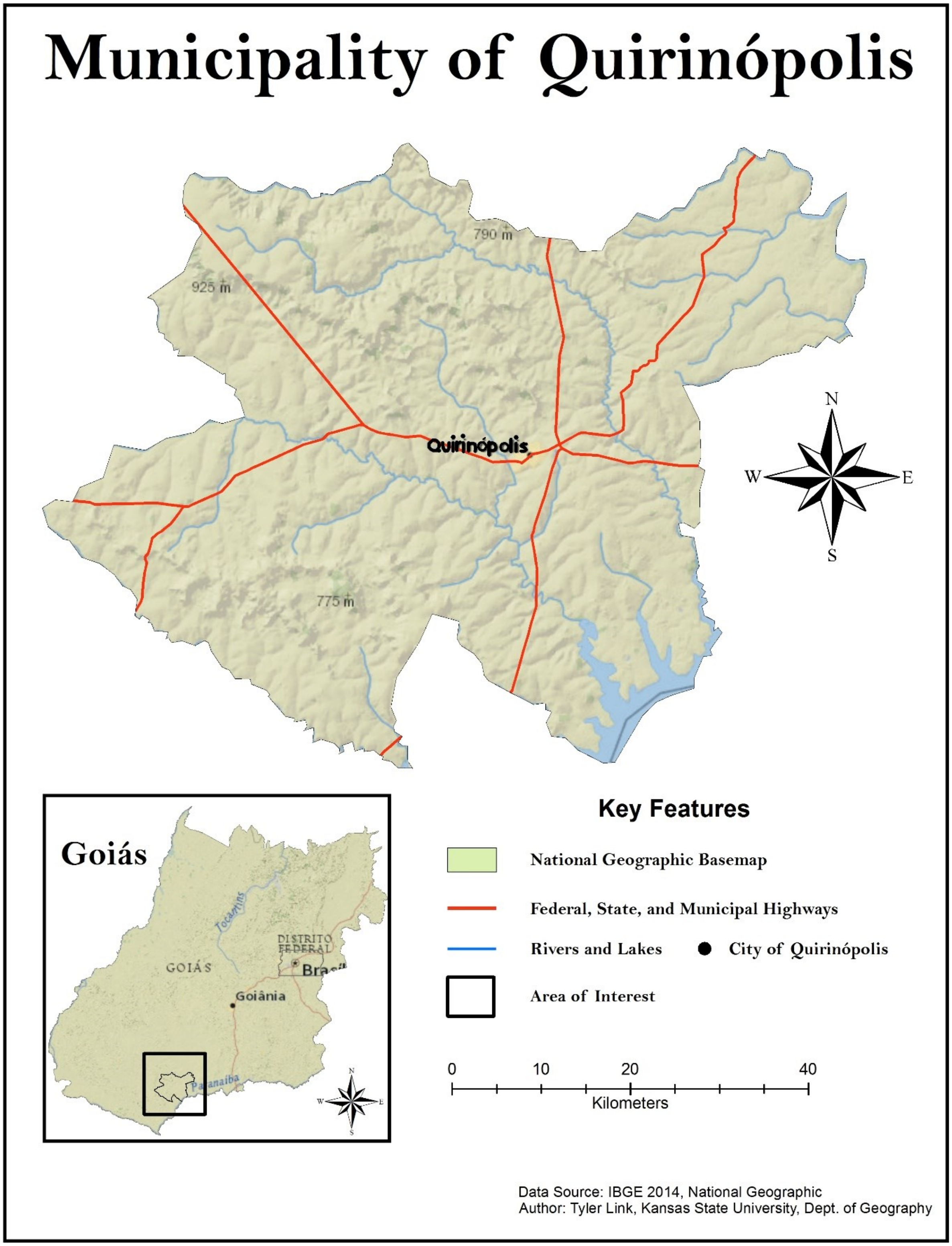


Figure 4.5 the municipality of Quirinópolis

4.2 Data Collection

The field data used in this thesis is part of a major dataset funded by the National Science Foundation grant, "Collaborative Research: Direct and Indirect Drivers of Land Cover Change in the Brazilian Cerrado: The Role of Public Policy, Markets Forces, and Sugarcane Expansion." This grant funded data collection in the states of Goiás and Mato Grosso do Sul. The data collection was divided into three phases.

Phase one involved identifying municipalities where sugarcane mills existed and determining the ownership structure. This process was completed using the catalog of Anuário da Cana 2013 (Brazilian Sugar and Ethanol Guide 2013), developed by ProCana. This guide gave the location of mills, the ownership structure, the type of mill, and the production levels of each mill. The guide contained information about the types of mills producing both sugar and ethanol and producing only ethanol. The guide did not provide all the information needed, due to the constant changing and consolidation of the industry. Therefore, further research was conducted to verify the ownership structure of all the mills throughout the states of Goiás and Mato Grosso do Sul by calling, emailing, and visiting each mills internet page until the results were found. For the purpose of this thesis, the state of Goiás was chosen due to its importance in sugarcane production. All the sugarcane mills' ownership structures were analyzed using information from the Brazilian Institute for Geography and Statistics at a municipal level to gather general characteristics for each municipality. Three municipalities were selected, each with a different ownership structure. One had a mill owned by a domestic firm, one was owned by a foreign firm, and the other was jointly-owned by both a domestic and foreign firm. These results were used to help plan the fieldwork route to be able to reach the farmers and urban residents within these municipalities.

Secondary data collection for socioeconomic data was obtained from the Brazilian Institute for Geography and Statistics at a municipal level for each of the selected municipalities. This data was compiled from the interactive website of *Atlas do Desenvolvimento Humano no Brasil* (The Atlas). The Atlas, developed by the United Nations Development Programme (UNDP), Institute for Applied Economic Research (IPEA), and the João Pinheiro Foundation (FJP), gathers over 200 demographic, education, income, employment, housing, and vulnerability characteristics from the 1991, 2000, and 2010 Demographic Census of Brazil for all of Brazil's 5,565 municipalities, 27 states, and 16 metropolitan areas. This rich dataset emphasizes the three dimensions of human development: a long and healthy life, access to knowledge, and standard of living. The dataset collects this information in order to rank the human development levels for each municipality, state, and metro area in Brazil. This dataset shows the progression of socioeconomic development for each municipality both before and after the introduction of the sugarcane ethanol mill.

The dataset contains more than 200 variables. However, for this thesis, I selected eight variables to evaluate the socioeconomic development over the past 20 years. The selected variables were Total Municipality Human Development Index (MHDI), MHDI for Income, MHDI for Longevity, MHDI for Education, Infant Mortality rate, Sanitation, Gini Index, and Theil – L Index. The first variable examined is the Total MHDI which is used as an indicator of human development. The Total MHDI was calculated by the geometric mean of the dimensions pertaining to the indices of income, education and longevity, calculated with equal weights. These three dimensions were also used for the socioeconomic development analysis (The Atlas, 2013). MHDI for Income was obtained by the Income per capita indicator using the following formula: [ln (observed value of the indicator) - ln (minimum)] / [ln (maximum) - ln (minimum)] where the minimum and maximum values are R$ 8.00 and R$ 4,033.00 (prices of August 2010) (The Atlas, 2013). MHDI for Longevity was obtained by the Life expectancy at birth indicator, using the following formula: [(observed value of the indicator) - (minimum)] / [(maximum) - (minimum)]m where the minimum and maximum values are, respectively, 25 and 85 years (The Atlas, 2013). Finally, MHDI for Education was calculated by the geometric mean of the sub-index of school attendance of children and young people (with a weight of 2/3) and the sub-index of the educational level of the adult population (with a weight of 1/3) (The Atlas, 2013).

All of these MHDI indicators are measured on a scale from 0 to 1, where 0 to 0.4999 is Very Low; 0.5 to 0.5999 is Low; 0.6 to 0.6999 is Medium; 0.7 to 0.7999 is High; and 0.8 to 1 is Very High. The Infant Mortality Rate variable is measured by the number of children that will not survive the first year of life, per 1,000 live births (The Atlas, 2013). The percentage of the population in households with piped water and toilets variable was calculated by the ratio of the population living in permanent private households with piped water in at least one of their rooms and an exclusive bathroom and the total population living in permanent private households, multiplied by 100. The water may be derived from general network, wells, springs or reservoirs fed by rainwater or tanker car. An exclusive bathroom is defined as a room that has a shower or a bath and a toilet unit (The Atlas, 2013). This thesis also used the Gini Index and Theil – L Index to examine the level of inequality within each municipality. The Gini Index measures the degree of inequality in the distribution of income per capita. Its value ranges from 0, when there is no inequality (the per capita household income of all individuals have same value) to 1, when inequality is at its maximum (only one person holds all the income). This measurement is limited to individuals who live in permanent private households (The Atlas, 2013). The Theil –L Index measures inequality in the distribution of per capita income, excluding those whose household income per capita is zero. It is calculated by a logarithm of the ratio between the arithmetic and geometric averages of the per capita household incomes of individuals: the index is zero when income inequality does not exist and tends to infinity when inequality tends to the maximum (The Atlas, 2013).

In addition to socioeconomic data, I collected data on agricultural production for the municipalities under study. The Agricultural Census data was gathered from the Brazilian Institute for Geography and Statistics and The Institute for Applied Economic Research (IPEA) at a state and municipal level. These datasets were used to examine the changes in crop production for different crop types. In particular the datasets helped to examine planted area in hectares of soybeans, corn, sugarcane, rice, beans, cotton, and number of cattle for each municipality under study to help support the remote sensing findings.

The data used in the empirical analysis collected information reflecting sugarcane farm characteristics taken from a farmer survey, a city survey, and remote sensing analysis. A team of fieldworkers, composed of Kansas State University graduate students and undergraduate students from Universidade Estadual Paulista (UNESP), Tupã campus, administered a nine-section survey during the months of June and July of 2014 throughout the Brazilian states of Goiás and Mato Grosso do Sul.

The second phase involved fieldwork in the state of Goiás. Fieldwork data collection consisted of three parts. The first part of the data collection process involved farmers interviews. This field survey collected information on the farmers' household demographics, number of people living in the farm, education level, income earnings from farm and non-farm activities, and whether the farm uses any government programs. In addition, the survey collected information about farm size and the initial land use prior to farming activities, landownership history, income from different farm activities, the knowledge of technical support and rural credit, irrigation, sugarcane production, crop type used prior to sugarcane, what problems occurred with sugarcane production, and if they harvest sugarcane manually or through mechanization. To finalize, the survey collected information about the farm distance to the mills, the knowledge of mill's production and ownership, mills impacts in the communities' wellbeing, and contracts, to compliment the data, I asked the farmers to identify specific fields within their farms. Using the farms identification, I created a polygon using QGIS, an open source GIS program.

The next part of the data collection involved the collection of farm histories for the polygons using QGIS in a Microsoft Surface Tablets. , which used QGIS, an open source GIS program. Within QGIS, the latest Landsat imagery from June 2014 was clipped to the study areas. The Landsat imagery helped the farmers to identify their farms, as well as the fields that the farmer had extensive knowledge on their farms. Once a field was identified, the I asked the farmers to give detailed descriptions of what types of crops were planted and grown monthly from January 2005 to June 2014. Polygons were constructed within QGIS with attribute fields. These attribute fields consisted of the survey number, municipality, and monthly crop type from January 2005 to June 2014. If a farmer had a detailed history of multiple fields, we repeated the process for additional fields within the farm.

Some farmers were unable to identify their farms or fields using QGIS because of the low-resolution imagery of Landsat. To solve this problem, I used Google Earth. Google Earth was used in two ways: first as a number of farmers use Google Earth to locate their farms on a regular basis, it was then easy for them to pinpoint the farm and field within Google Earth, and then I was able to locate the field on QGIS; second, whenever this process did not succeed, I created a KMZ polygon within Google Earth and manually wrote the attributes within the survey itself. Later these polygons were processed and uploaded into QGIS and the attribute fields were added from the survey. Another tool was also used to obtain the location of the farm and create polygons. All fieldworkers were given a Garmin GPSMAP62. Due to the need to manually walk or drive around these massive fields, this tool was generally used to help find the location of the farm, which was then used as a starting reference within QGIS or Google Earth.

The final part to the data collection was a city survey, which was given out randomly throughout the study areas cities to urban residents. Student researchers asked business employees, owners, and various individuals in public places if they would be willing to participate in a voluntary research study on the impacts of sugarcane in their communities. The survey itself was small and only took 10 to 15 minutes to complete. The students collected 54 surveys in Quirinópolis and 84 surveys in Edéia and Caçu, for a total of 222. This survey compiled data on the gender, education level, and income of each participant, and it asked questions involving how the sugarcane mill has impacted their community, environment, health, economic, and social development. These questions of perception used the Likert Scale, which was developed by Rensis Likert. This common sociology classification technique asks questions, which the respondent can then answer from a range that goes from Strongly Disagree to Strongly Agree.

Once the fieldwork was completed, the data was processed into Microsoft excel spreadsheets. Descriptive statistics were developed for the dataset. Due to the low number of farmers throughout the three municipalities, all the farmers were grouped together for a total of 33. The questions were then divided up into three categories to be better represented: Community Well-Being, which included the variables Social Life (e.g. new bars, restaurants, and entertainment), Security, Wildlife (e.g. quality of rivers, numbers of native animals), and Quality of Life; Socioeconomic Development which included the variables of Public Health (e.g. hospitals and doctors), Private Health (e.g. dentists and eye doctors), and Education; and Infrastructure Development, which included the variables of Roads, Basic Infrastructure (e.g. waste management, street lighting, and affordable housing) and Economic Development (e.g. new business and jobs). Due to the low number of our sample size for both farmers and the city surveys, the Likert Scale questions had to be grouped together, with Strongly Disagree and Disagree in one category, Strongly Agree and Agree in another, and Neither Agree or Disagree, for a total of three classes.

Field data collection in the Cerrado is not an easy task. Often we had to travel two to four hours in one direction along highways and secondary roads to reach a farm. In total, the research team traveled 3,546.6 kilometers (2203.8 miles) across the Cerrado. Many farms in the region are massive, requiring the distance between them to be large as well. Consequently, the remoteness of farm locations made time a serious constraint on data acquisition. Furthermore, farm locations and meetings were not always precise, sometimes even more time was lost by our team being unable to find a farm, or by the farmer not being at home when a meeting was scheduled. In addition, each interview normally would take between one and three hours, which made it difficult to complete many interviews each day.

Nevertheless, the research team was able to achieve the maximum number of interviews that was possible by mapping out a tentative route that crossed through known sugarcane expansion areas within the states of Goiás and Mato Grosso do Sul. Three cars were also allocated for the research to interview at multiple locations at once. Prior to arriving at each new city and municipality, the rural syndicates were contacted to provide lists of farmers in the area.

These lists were used to call the farmers to schedule interviews at their farms, houses within their respected cities, or even at the rural syndicates.

The interviews were random selection since we had no control who we would interview. The research team interviewed small-scale farmers living in modest town homes to multi-million dollar farmers with larges estates. Farmers generally were adult males who owned the farm. Some interviewees were very responsive to the interview process, while others were not interested and were sometimes even skeptical of our intentions during the interview. The length of the interview, which could be as long as three hours, seemed to be a problem for some of the interviewees. Interestingly, some farmers were hesitant to give the exact size of their farm. This may have been due to the Legal Reserve, which is required to take up 20% of their land, and it is possible that some farmers did not want to admit to not obeying this law. Some farmers were also hesitant to give the exact amount of money the farm was making. Furthermore, during the contract section, which describes the relationship the farmer has with the mill or mills within the region, many farmers seemed to be cautious about what they said about the mill.

Time constraints were also a limitation for the city surveys. For example, in Quirinópolis only two student were able to interview urban residents due to the higher number of farmers being interviewed at the same time. As for Edéia and Caçu, only one day was given to complete the urban surveys for each city, so a larger sample could not have been accomplished.
Although sample sizes could represent a limitation to this thesis, understanding the perceptions that the sugarcane industry has had on farmers and urban residents throughout the study area is vitally important to complete a more holistic understanding of the impacts the sugarcane industry has on the people, environment, and economy. Also important is the evaluation of how these

perceptions are similar and/or different across different municipalities, which have different ownership structure of the sugarcane mills.

4.3 Research Design

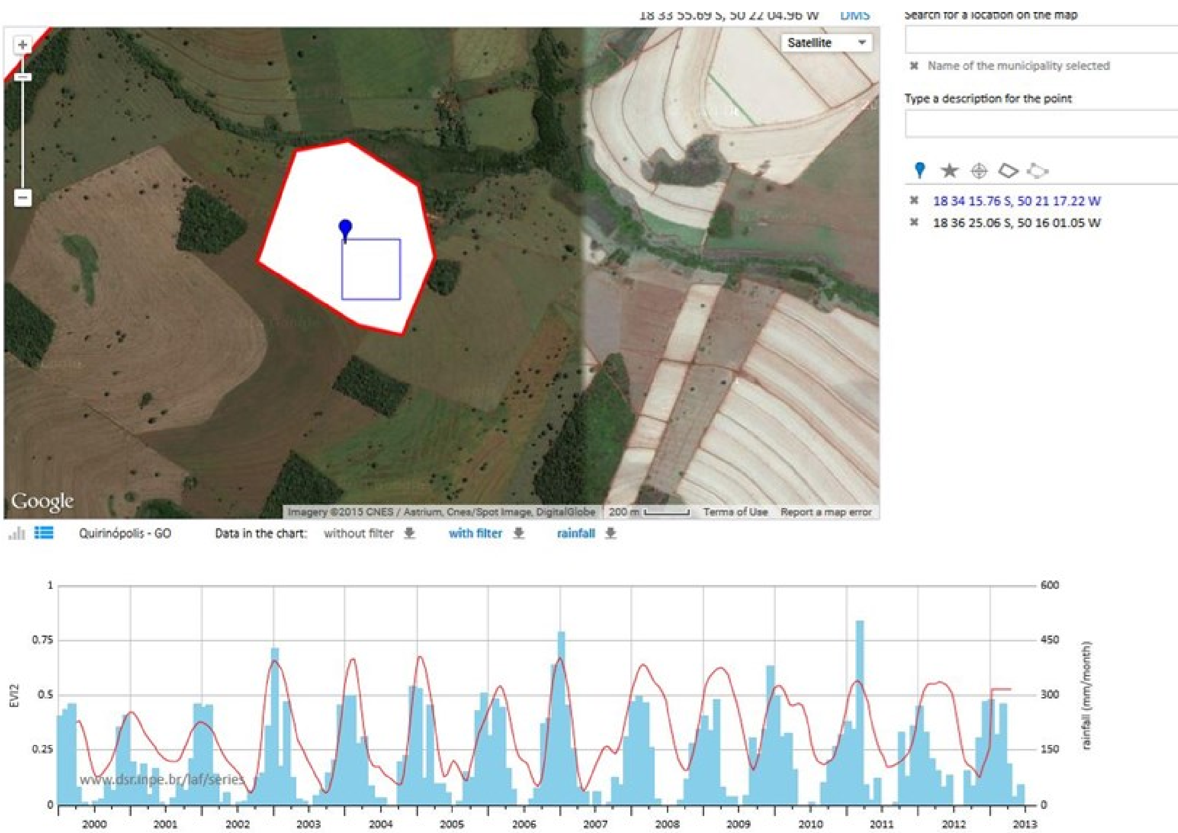
4.3.1 Remote Sensing and Geographic Information Systems (GIS)

One of the main objectives of this thesis is to evaluate the effects of the mills' structural organization on land use in these municipalities. Prior to 2005, sugarcane was nonexistent in the study areas (Canasat, 2012). Understanding what the prior land use was before sugarcane came to the region is helpful to determining if sugarcane is expanding on native vegetation, other crops, or pasture land. In order to meet this objective, ground reference points were needed. The interviews gathered detailed information about the farms and whether or not the farmers produced sugarcane on their lands. The interviews involved gathering polygons of agricultural fields using Google Earth KMLs, Garmin GPSMAP 62, and QGIS software from farmers as seen in figures 4.6 and 4.7. The farm-use history polygons collected monthly crop or land use data from 2005 through June 2014. A total of 137 polygons were gathered from this process.

Figure 4.6 collection of farm history polygons

These 137 farm history polygons were then processed in ArcGIS. A total of 13 farm history polygons were marked as unusable due to fieldwork collection errors leaving a total of 124 farm history polygons. In order to verify the accuracy of these farm history polygons, I used a web-based time series tool, developed by the Brazilian National Institute for Space Research (INPE). The INPE time series tool represents a particular pixel of vegetation's change over time along the two-band Enhanced Vegetation Index (EVI2). EVI2 uses MODIS images from the MOD13, Q1 product (collection 5, 16 days composite, and spatial resolution of 250 m) (Jiang et al., 2008; Freitas et al., 2011). The INPE time series tool was designed to allow users to upload shapefiles over their research areas. Next, users can select a pixel over their research interests and obtain EV2 data. This data is processed and visualized by an EVI2 spectral-temporal profile from 2000 through 2014. In addition, the INPE time series tool collects rain fall totals and gives the minimum, maximum, average, median, variance, sum, and samples for a given location as seen in Figure 4.7 (Freitas et al., 2011).

The INPE time series tool was used in two ways. First, in order to become more familiar with the EVI2 spectral-temporal profiles of various crops, native vegetation, pastures, and sugarcane, the tool was used to classify the farm history polygons. A total of 30 farm history polygons were deselected to provide a control for this first classification process. Thus, I uploaded the remaining 94 farm history polygons into the INPE time series tool. The 94 farm history polygons were also uploaded into ArcGIS to correspond with the farm history polygons within INPE time series tool. A World Imagery base map using Google high resolution 30 cm, 60 cm imagery and low resolution imagery 15m imagery was used in ArcGIS in order to correspond to INPE time series, as seen in Figure 4.8. Next, I selected a polygon in ArcGIS. Then, this polygon was found within the INPE time series tool. Once found, the central-most pixel within the farm history polygon was selected. Finally, I classified the farm history polygon in the following categories, sugarcane, annual crops, and pasture/Cerrado using the EVI2 vegetation spectral-temporal profile on a yearly basis from 2001 through 2012. These results were entered into ArcGIS for all 94 polygons on a yearly basis from 2001 through 2012. Afterwards, the vegetation spectral profiles were downloaded onto the Kansas State University server for future use in developing classification modeling techniques.



Statistical data: without filter with filter rainfall Period: year calendar crop year

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
minimum	0.1315	0.1987	0.0562	0.0565	0.0949	0.1112	0.0864	0.0634	0.1594	0.1618	0.1865	0.1732	0.1256	0.2634
maximum	0.4099	0.4250	0.6240	0.6618	0.6698	0.6816	0.6516	0.6766	0.6462	0.6284	0.5467	0.5691	0.5644	0.5317
average	0.2596	0.2958	0.2596	0.3170	0.3103	0.3201	0.3452	0.3004	0.4248	0.4453	0.3629	0.3407	0.3841	0.4978
median	0.2468	0.2842	0.2359	0.2730	0.2097	0.2497	0.3280	0.2616	0.4792	0.4796	0.3725	0.2879	0.4602	0.5315
variance	0.0095	0.0058	0.0218	0.0405	0.0410	0.0364	0.0294	0.0307	0.0292	0.0239	0.0168	0.0205	0.0284	0.0079
sum	4.4127	6.8042	5.9714	7.2905	7.1366	7.3632	7.9388	6.9094	9.7700	10.2412	8.3468	7.8360	8.8338	3.9826
samples	17	23	23	23	23	23	23	23	23	23	23	23	23	8

Figure 4.7 INPE time series graphical interface showing the red line as the filtered vegetation curve, the blue bar graph as precipitation totals, and summary statistics below.

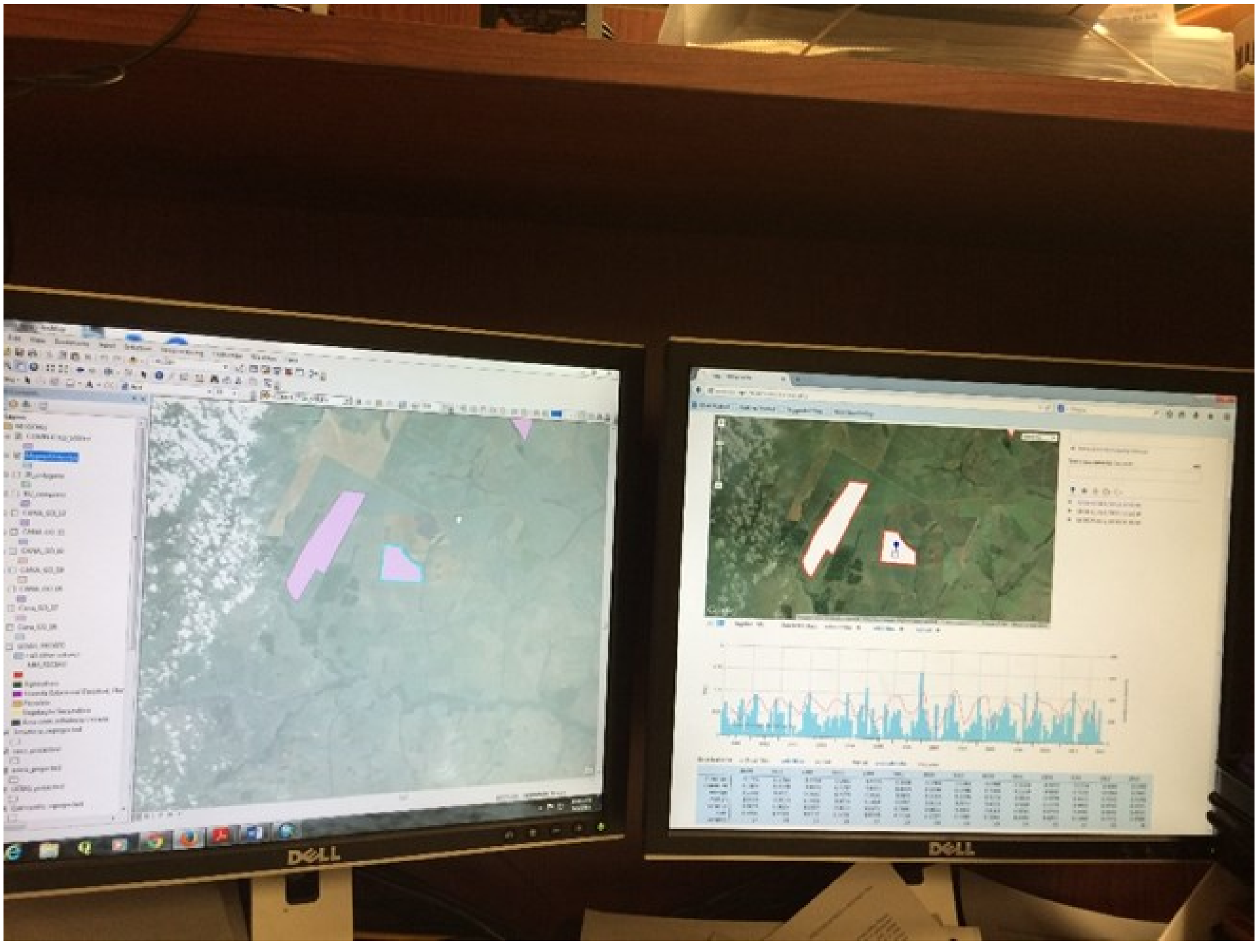


Figure 4.8 ArcGIS and INPE time series tool for verification of farm history polygons

The EVI2 vegetation spectral profiles used to identify vegetation type follows the work by Brown et al. (2013); Coutinho et al. (2013); and Rudorff et al. (2009). These authors classified agricultural land use for multiple years using a time series MODIS vegetation index for Brazil. Brown et al. (2013) identified crop types between annual soy crops, different variations of soy double crops, cotton, and pasture. Brown et al. (2013) gave detailed monthly vegetation profiles for all of these crop types, as presented in Figure 4.9. However, the research by Brown et al. (2013) was not interested in mapping sugarcane, which is why this thesis also factored in the work developed by by Coutinho et al. (2013). Coutinho et al. (2013) developed a methodology for mapping various crops, including sugarcane, in Mato Grosso do Sul, Brazil. Coutinho et al., (2013) also utilized MODIS sensor system toward mapping and monitoring crops. Figure 4.10 below shows sugarcane spectral-temporal profiles of vegetation as well as other vegetation types.

The previous two studies used NDVI spectral-temporal profiles to classify vegetation. Rudorff et al. (2009) used EVI/MODIS data time series data to identify land use prior to sugarcane expansion in the Brazilian state of Paraná. Rudorff et al. (2009) used the temporal nature of the EVI curves to differentiate between pasture, annual crops, and sugarcane. Figure 4.11 indicates the EVI spectral curves for pasture converted into sugarcane, annual crop converted into sugarcane, and a transition from pasture into annual crop, then into sugarcane. By combining these research, this study is able to distinguish various crop types, pastures, and native vegetation in order to be replicated for the sugarcane polygons collected from the fieldwork.

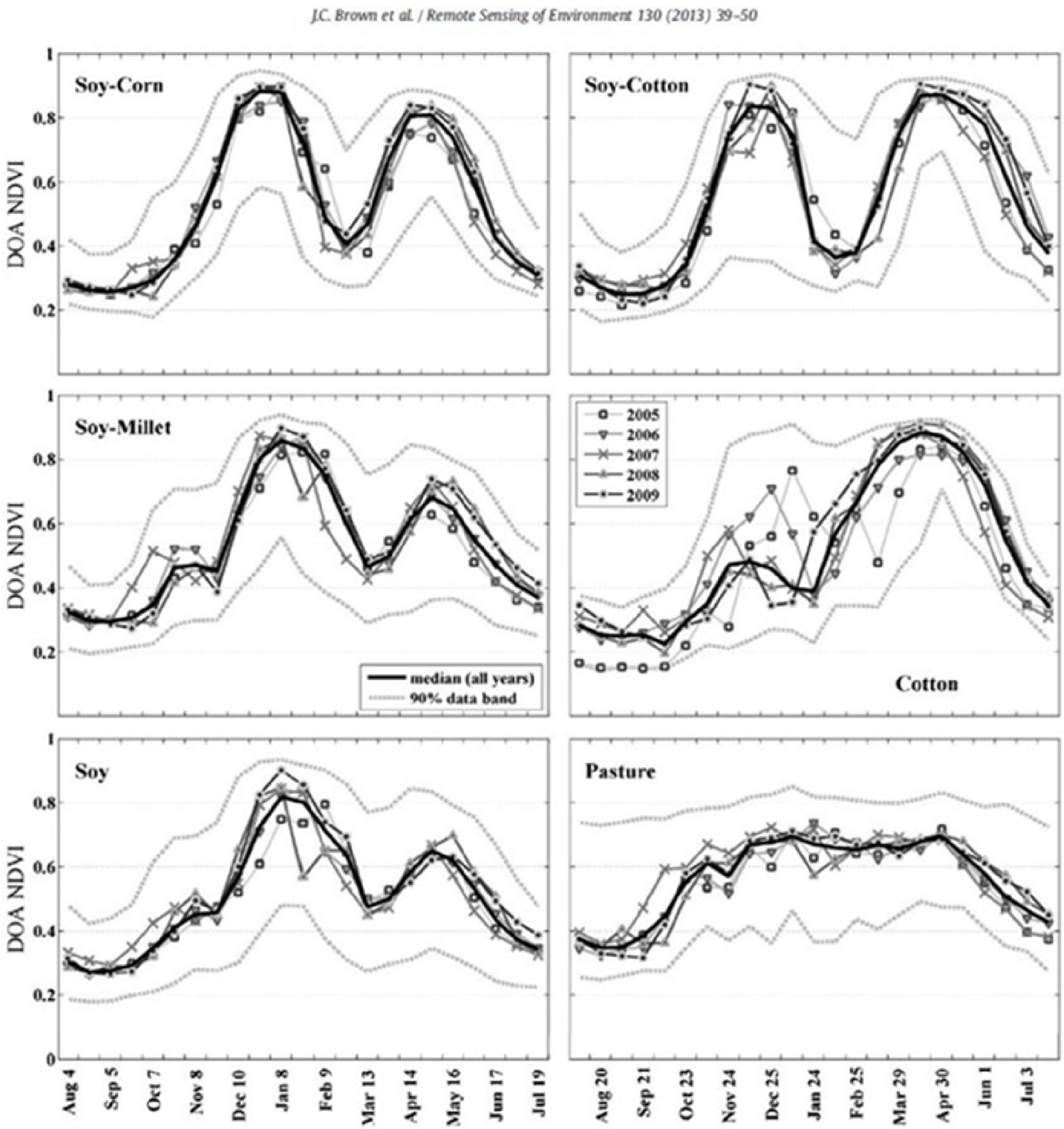


Figure 4.9 NDVI spectral-temporal profiles of vegetation index developed by Brown et al. (2013)

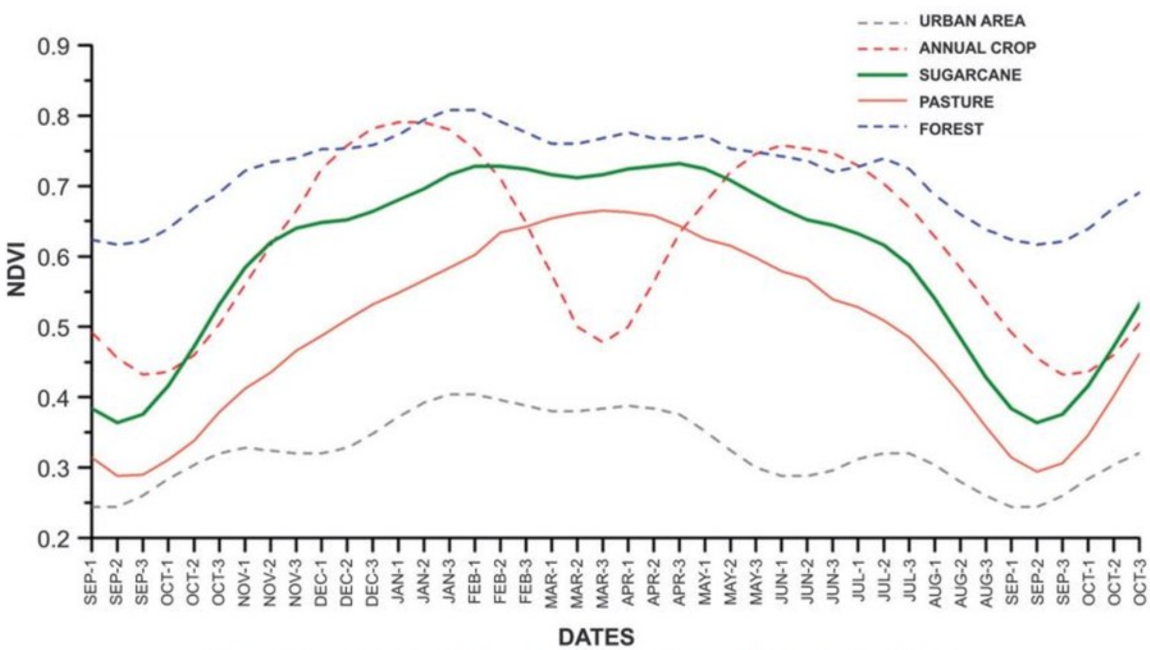


Figure 1 – Spectral-temporal profiles of the vegetation index from different targets

Source: Fernandes (2009).

Figure 4.10 NDVI spectral-temporal profiles of the vegetation index developed by Fernandes (2009) and Coutinho et al. (2013)

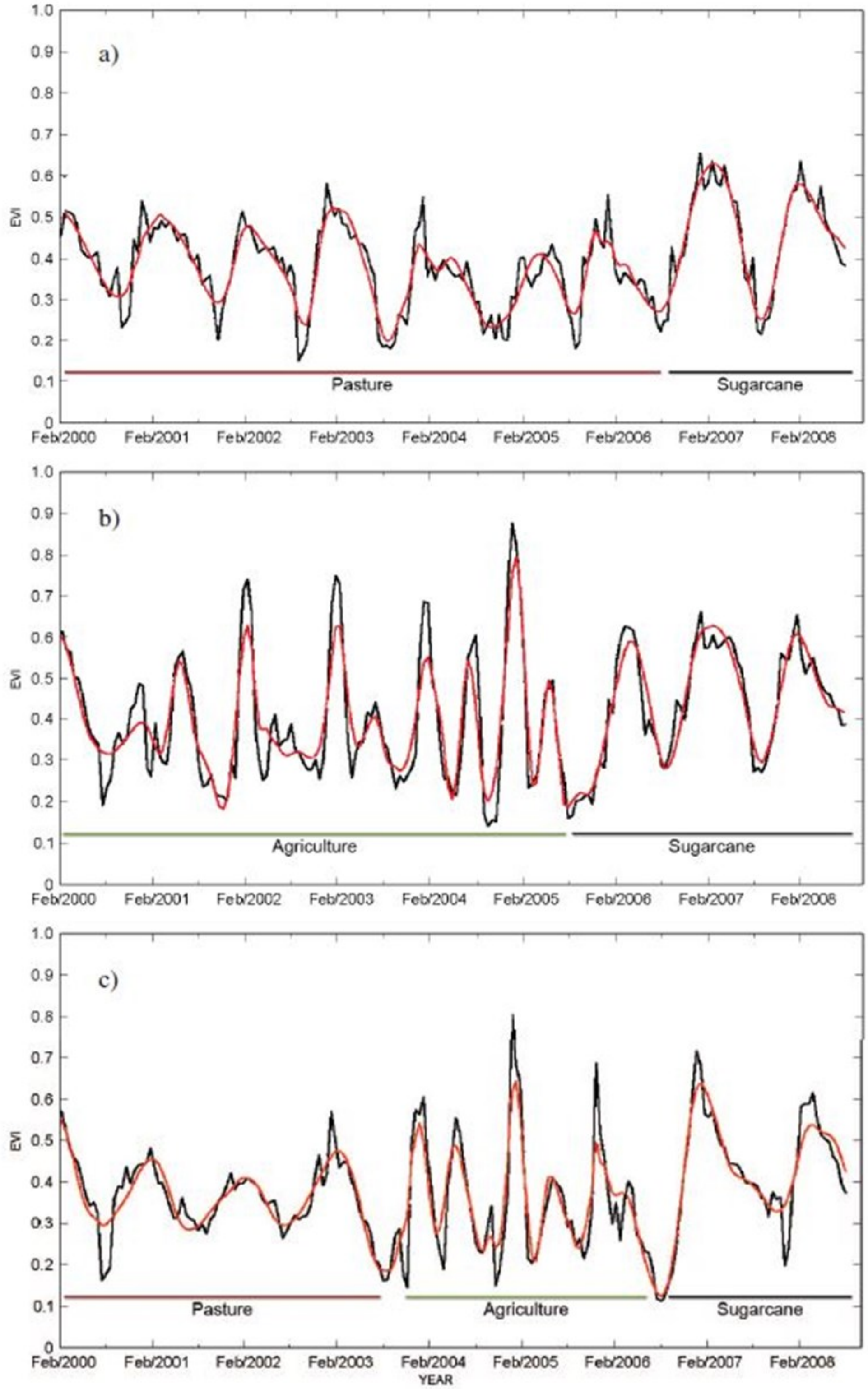


Figure 4.11 EVI/MODIS time series. (a) pasture to sugarcane; (b) annual crop to sugarcane; (c) transition from pasture to annual crop to sugarcane. Developed by Rudorff et al., (2009).

It is important to note that the spectral profiles from the Brown et al. (2013), Coutinho et al. (2013), and Rudorff et al. (2009) did not specify the difference between native Cerrado vegetation and pasture. Thus, I expanded their work by examining what types of land use sugarcane has expanded on. In other words, I classified my images to detect the difference between native Cerrado vegetation and pasture. However, determining the difference between Cerrado vegetation and pasture is a difficult process and numerous scholars had difficulties in distinguishing between native Cerrado vegetation and pastures due to the similarity in their spectral profiles (Sano et al., 2010; Sano et al., 2000; Ratana and Huete, 2005; Kawakubo et al., 2009; Arvor et al., 2011).

In order to differentiate native Cerrado vegetation from pasture and to validate my own land use classifications, I used the Conservation and Sustainable Use of Biological Diversity (PRIOBIO) dataset. PROBIO classified vegetation types throughout Brazil in the year 2002. PROBIO, which stands for Conservation and Sustainable Use of Diversity Biological, is a project under the Ministry of Environment of Brazil and receives financing from the World Bank and Global Environment Facility. PROBIO classified land use throughout the 200 million acres of the Cerrado biome for the year 2002 including the state of Goiás as seen in Figure 4.12. Due to the Cerrado's large geographical coverage, PROBIO used a collection of 121 Landsat ETM+ scenes, each scene with a 185 km X 185 km area, during the August to October dry season to reduce the amount of cloud interference. These PROBIO images were later mosaicked and cut to fit the Cerrado's biome outline produced by IBGE. The images were mapped into these classes: cultivated agriculture, pastures, reforestation, urban areas, water, degraded mining, and different types of natural vegetation. In order to verify their results, Global Accuracy and Kappa statistical methods were used which resulted correctly identifying 74.19% and 68.31% for each method.

The PROBIO dataset indicated that the validation numbers were lower due to the difficulty differentiating the similar spectral behavior between pastures and cultivated agriculture.

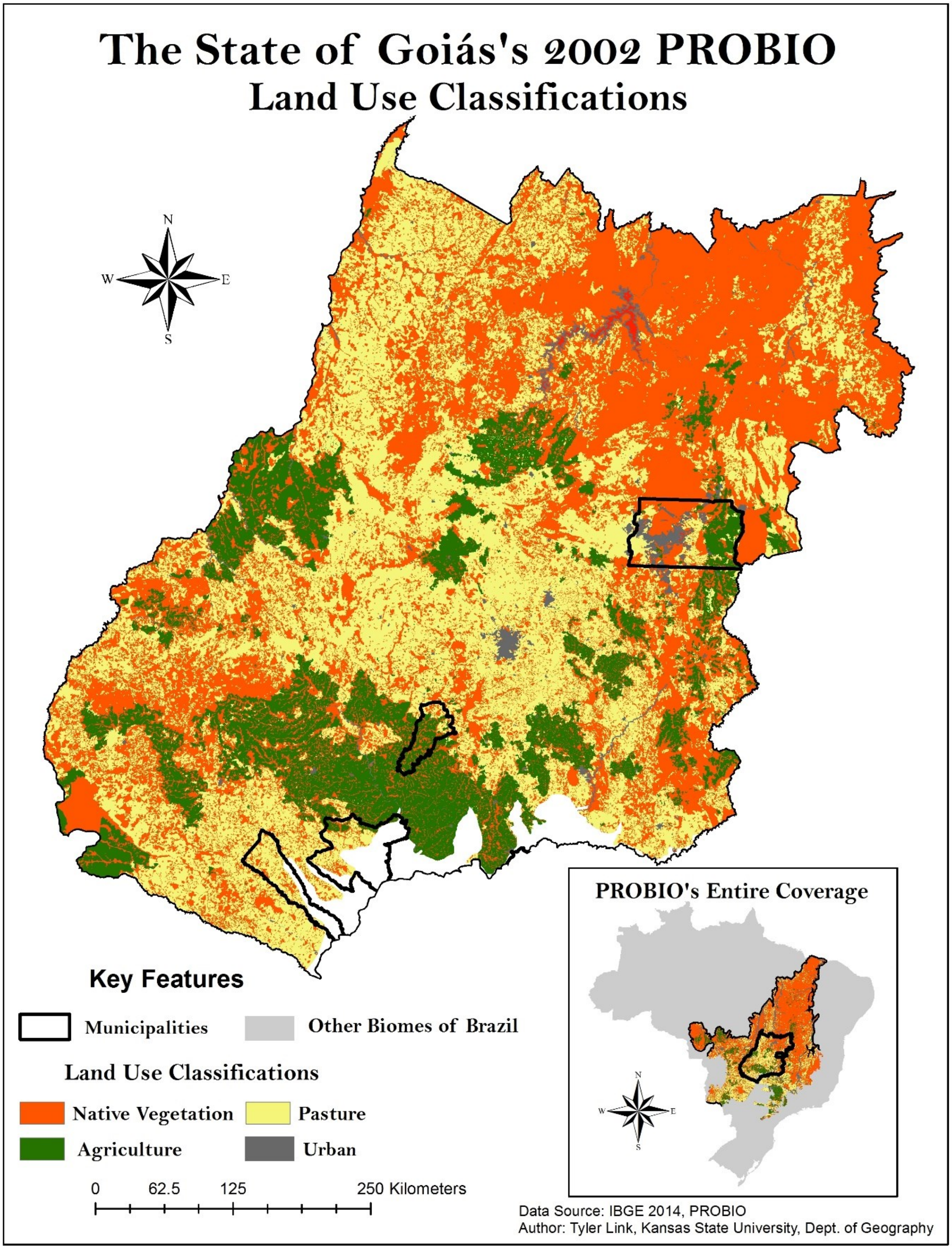


Figure 4.12 The State of Goiás's 2002 PROBIO Land Use Classifications

Thus considering that PROBIO dataset has a high accuracy rate, I used it to differentiate between pasture and native Cerrado vegetation for the state of Goiás. Using PROBIO, I created 30 polygons for each the native Cerrado vegetation and pasture as a training sample. Afterwards, these polygons where then added to the INPE time series tool. The centermost pixel within the polygons was than selected to examine the EVI2 spectral-temporal profiles for the year 2002. These training samples helped discover trends that were used to separate native Cerrado vegetation and pasture. The biggest difference between the two classes was the native Cerrado vegetation tended to have a higher EVI value through the start of the dry season. Whereas pastures tended to lose their EVI values faster in response to the start of the dry season. Although my training sample was small, this trend was consistent with Ratana et al. (2005) that also found pastures lost their EVI values at the start of the dry season faster than that of native Cerrado vegetation.

Although PROBIO dataset was useful in differentiating native Cerrado vegetation and pasture, it did not cover the entirety of my study area. Southeastern Caçu and southern region of Quirinópolis is located in the transitional zone from the Cerrado and the Atlantic forest biomes. Although PROBIO dataset classified land use for all the biomes in Brazil, neither the Cerrado nor the Atlantic forest classification research teams mapped this transitional zone.

Therefore this study used a multi-step classification technique to help verify the area planted in sugarcane. First, a large dataset of sugarcane polygons, acquired from Canasat[3] was used to show the expansion of sugarcane throughout the entire study area. I downloaded the

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[3] Canasat produces annual sugarcane maps for Brazil by using remote sensing images from the Landsat-5 satellite and alternatively from Landsat-7, CBERS-2 and Resourcesat-I satellites, which are freely available at INPE/DGI. The image processing and interpretation are carried out using the SPRING software.

sugarcane polygons for the crop year of 2012 for the state of Goiás as Figures 4.13, 4.14, and 4.15 demonstrates. These sugarcane polygons were clipped within ArcGIS to each municipality under study. Thus, Edéia had 77 sugarcane Canasat polygons in 2012; Quirinópolis had 474 Canasat sugarcane polygons in 2012; and Caçu had 85 Canasat sugarcane polygons in 2012.

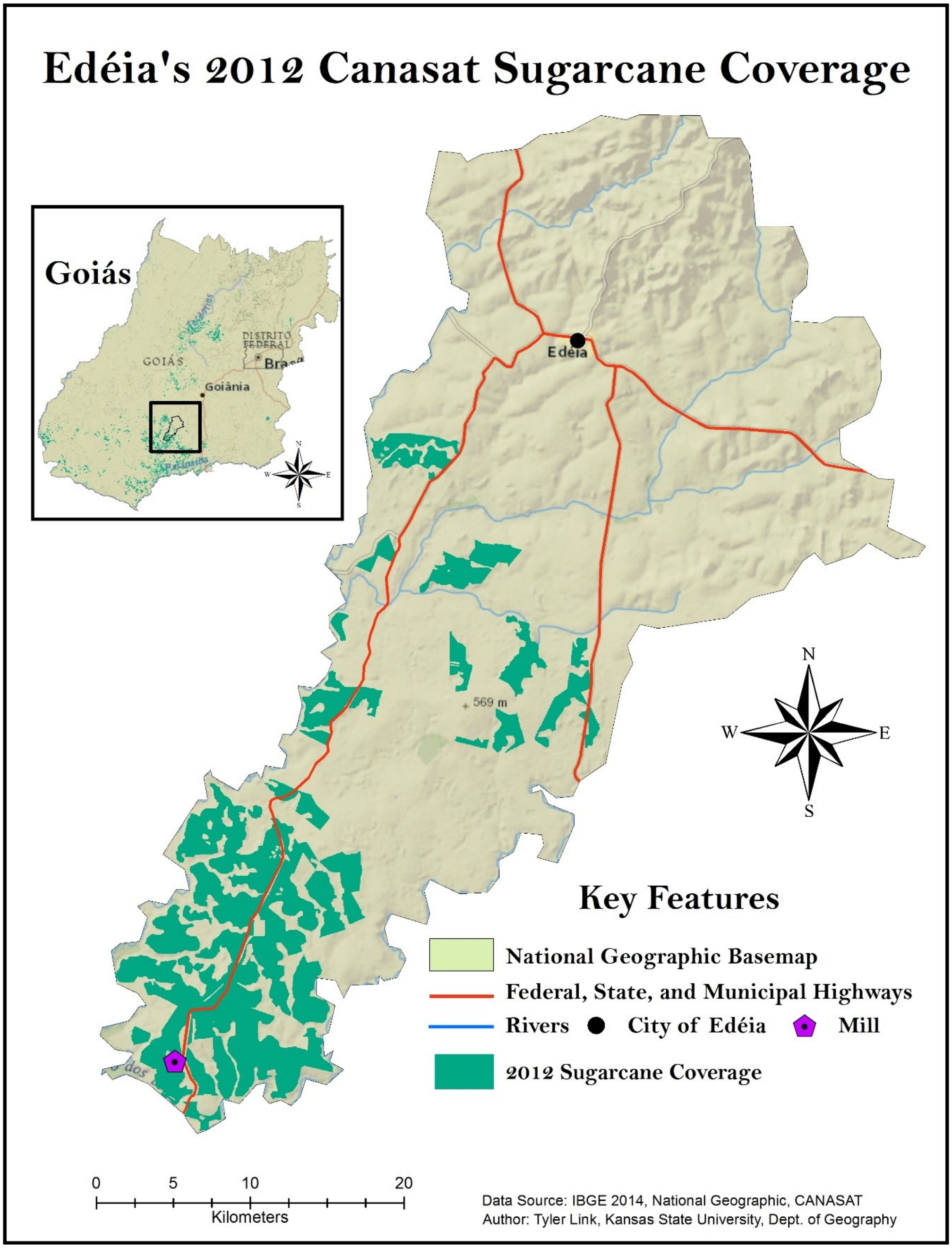


Figure 4.13 Edéia's 2012 Canasat Sugarcane Coverage

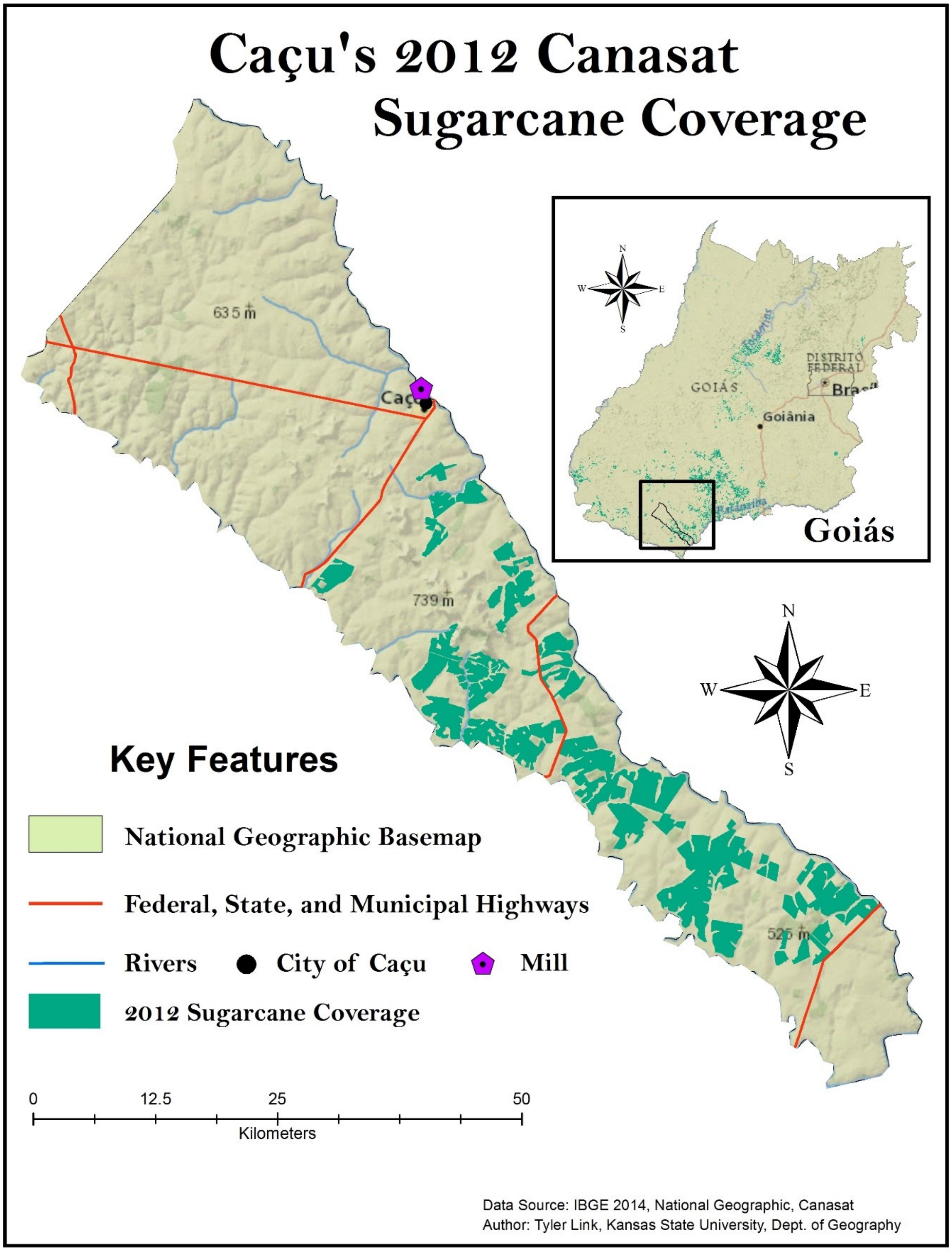


Figure 4.14 Caçu's 2012 Canasat Sugarcane Coverage

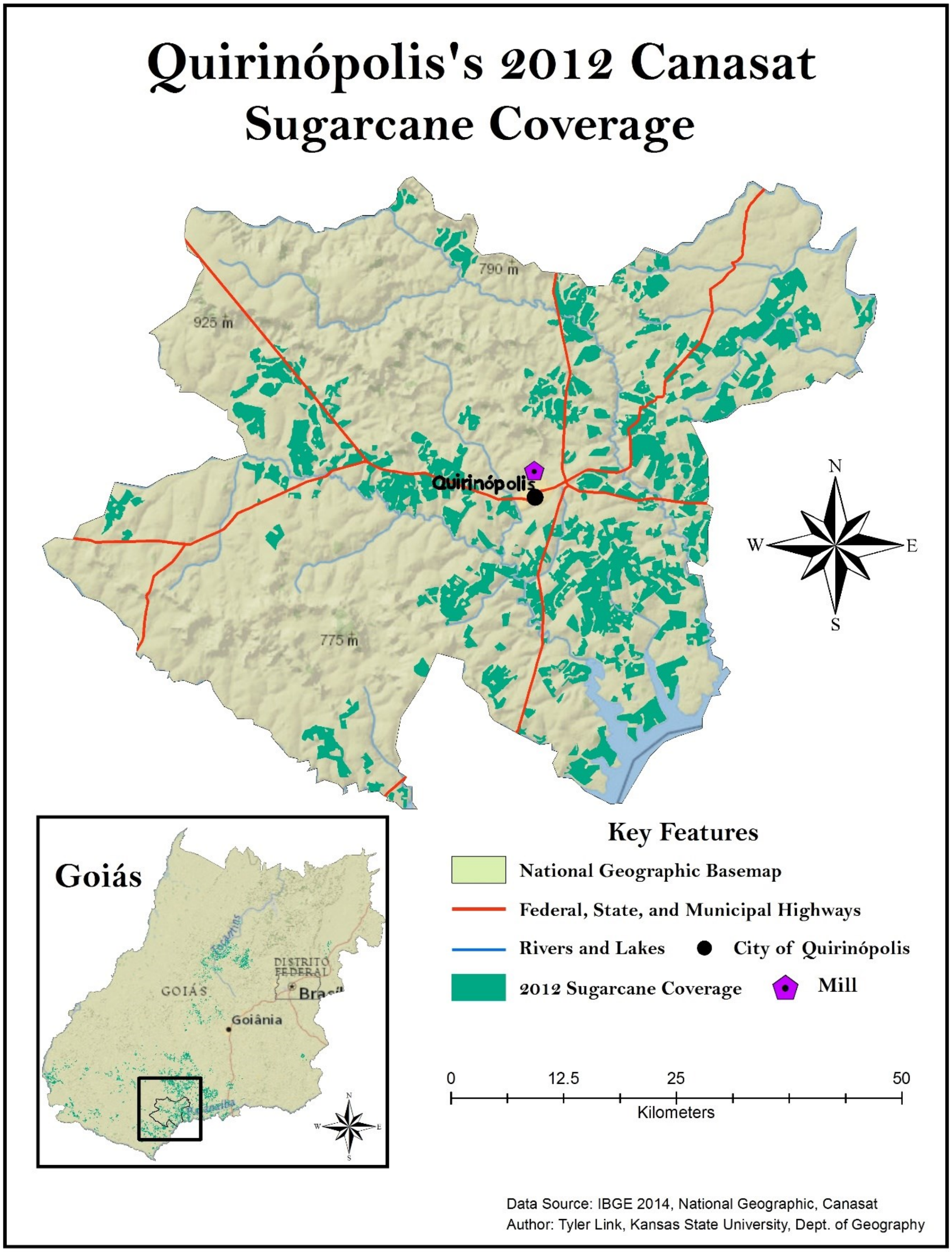


Figure 4.16 Quirinópolis's 2012 Canasat Sugarcane Coverage

In addition to the PROBIO dataset and Canasat sugarcane polygons, Landsat ETM+ images were also used. These images were downloaded from the USGS Global Visualization Viewer (GloVis). Two Landsat scenes, 222/72 and 222/73, were used. These scenes were collected during the months of August to October, images used by PROBIO dataset. The band combinations consisted of band 4 (0.76 - 0.90microns), band 5 (1.55 - 1.75 microns), and band 3 (0.63 - 0.69). This band combination was selected due to its ability to give many variations in color tone for different vegetation types. The Landsat ETM+ images were used for two reasons. First, these images were used to help identify between pastures and native vegetation due to their close EVI2 spectral-temporal profiles. As described in the research done by the PROBIO research team, one way to distinguish between the two classes was to understand their shapes. Planted pastures in particular have regular geometric shapes, which show human intervention, while natural vegetation has irregular shapes. Second, due some of these sugarcane polygon fields were quite large they had multiple fields within them. The Landsat ETM+ images were used, with the INPE time series tool, to separate sugarcane polygons if there were multiple vegetation types prior to become sugarcane.

In the next step, I uploaded the Canasat sugarcane polygons for 2012 into the INPE time series tool. Similar to the process of verifying the fieldwork datasets, ArcGIS was used to verify the polygons and to select the Canasat sugarcane polygons for each municipality. A polygon was then selected in ArcGIS. Next, the same polygon was found within the INPE time series tool. Some of the Canasat sugarcane polygons were quite massive and had multiple land uses in 2002. In order to identify if these massive sugarcane polygons had multiple land uses in 2002, the Landsat ETM+ images were added to ArcGIS to help separate sugarcane polygons with multiple land uses. A total of 40 sugarcane polygons needed to be split up due to multiple vegetation types. This process was completed using the Cut Polygons Tool. Once this process was complete, the centermost pixel was selected within each polygon. This thesis used three classes to classify the land use types: Native Vegetation, Pastures, and Agriculture. This classification was based on the works of Brown et al. (2013); Coutinho et al. (2013); and Rudorff et al. (2009). Afterward, the pixel data was downloaded for each Canasat sugarcane polygon. The EVI2 spectral-temporal curve was examined for the year 2002 for all three municipalities. In order to examine a land use transition, a second year was selected for each municipality. The criteria used to select the second year was two years prior to sugarcane mill start of operations in order to see, if any, changes in land use from 2002. Therefore the years 2005 for Quirinópolis, 2006 for Edéia, and 2007 for Caçu were selected for the additional classification and their EVI2 spectral-temporal profiles were also downloaded to the Kansas State University Geography server for future land use land cover research.

Once this process was complete, in order to help validate my EVI2 spectral-temporal land use classifications, the PROBIO dataset was loaded into ArcGIS. Then, PROBIO dataset was run through the geoprocessing Clip tool to each municipality. The Clip tool extracts the input features, (PROBIO and the newly classified Canasat sugarcane polygons) that overlays the clipped feature (municipalities). Afterward, the clipped PROBIO dataset and clipped CANASAT sugarcane polygons for each municipality were run through another geoprocessing tool called Intersection. The Intersection tool calculates the geometric intersection for any number of feature classes and feature layers. The features, or portion of features, that are common to all inputs will be written to the output feature class. The final output for the Intersection tool overlaid the 2012 Canasat sugarcane polygons over the PROBIO dataset classifications. For clarity, the output for the 2012 Canasat sugarcane polygons intersection with the PROBIO dataset classifications will be referred to as (CPI) land use classifications. For my study area the only case where CPI land use classification covered the entire area was Edéia. Unfortunately, the CPI land use classifications only covered 44.41% of Caçu and 23.79% of Quirinópolis. Although the entire area of sugarcane expansion wasn't covered, the CPI land use classifications were crucial toward the validating my EVI2 spectral-temporal land use classifications. Statistics were computed comparing my EVI2 spectral-temporal land use classifications for the Canasat sugarcane polygons and the CPI land use classifications.

To support the remote sensing results, I collected data on agricultural land use for the municipalities. The Agricultural Census data was gathered from the Brazilian Institute for Geography and Statistics and The Institute for Applied Economic Research (IPEA) at a state and municipal level. These datasets were used to examine the changes in area planted for different crop types in hectares (ha). In particular the datasets examined areas with soybeans, corn, sugarcane, rice, beans, cotton, and number of cattle for each municipality under study. The years selected matched the remote sensing and GIS research. The year 2002 was selected for all three municipalities, 2005 was selected for Quirinópolis, 2006 was selected for Edéia, and 2007 was selected for Caçu. The year 2011 was selected due to it being the latest year that had complete planted area records for the crops under study.

4.3 Socioeconomic Development

The second objective of this thesis is to compare how domestic-owned mills, foreign-owned mills, and jointly-owned mills affect socioeconomic development on the municipalities. The structure of the research had two components. First, the socioeconomic indicators were downloaded from the Brazilian Institute for Geography and Statistics for the whole of Brazil and Goiás, and at a municipal level for each of the municipalities. This data was compiled from the interactive website of *Atlas do Desenvolvimento Humano no Brasil* (The Atlas). I chose eight indicators based on their ability to showcase the core concepts of socioeconomic development. Key concepts in studies of socioeconomic development include measurements of a long and healthy life, measurements of knowledge accessibility, measurements of standards of living, and measurements of inequality. Thus, the indicators selected were Total Municipal Human Development Index (MHDI), MHDI Income, MHDI Longevity, MHDI Education, Infant Mortality, Sanitation, Gini Index, and Theil -L Index. These indicators were obtained for 1991, 2000, and 2010 in order to show the progression of socioeconomic development over the past 20 years. More importantly for this thesis, these indicators helped to determine the socioeconomic impacts the sugarcane industry has had for these municipalities over the past 10 years. Once downloaded, this data was organized and produced in Excel.

The socioeconomic development indicators gathered from The Atlas were crucial towards developing survey questions, which were then used during the fieldwork. Once the fieldwork was completed, the data was processed into Microsoft excel spreadsheets. Next descriptive statistics were run for the entire sample for the city survey, and individually for each city. In total, 54 surveys were completed in Quirinópolis and 84 surveys were conducted for Edéia and Caçu for a total of 222. Due to the low number of farmers throughout the three municipalities, all the farmers were grouped together for a total of 33. The questions were then divided up into three categories: Community Well-Being, which included the variables Social Life, Security, and Quality of Life; Socioeconomic Development, which included the variables of Public Health, Private Health, and Education; and Economic Development, which included the variables of Roads, Basic Infrastructure, and Economic Development.

Chapter 5 - Results and Discussion

This chapter first examines the remote sensing and GIS land use and land cover change results are discussed for each municipality. Second, this chapter presents the results by examining trend of Goiás agriculture in the past decade. Third, it presents and analyzes the results of the sugarcane expansion on development over the past twenty years for each municipality using census data and the survey data.

5.1 Remote Sensing and GIS Results

Using the CPI land use classifications, I was able to identify three types of land use; native vegetation, agriculture, and pasture (Figures 5.1, 5.2, 5.3 and Tables 5.1, 5.2, 5.3). However, when the PROBIO dataset was developed it did not cover the whole state of Goiás. For my study area the only case where PROBIO dataset was able to cover the whole 2012 Canasat sugarcane polygons was for Edéia. Unfortunately, two of my study areas were impacted with only 44.41% of Caçu and 23.79% of Quirinópolis of the 2012 Canasat polygons were intersected with the PROBIO dataset. Southeastern Caçu and southern region of Quirinópolis is located in the transitional zone from the Cerrado and the Atlantic forest biomes. Although PROBIO dataset classified land use for all the biomes in Brazil, neither the Cerrado nor the Atlantic forest classification research teams mapped this transitional zone.

The results for the CPI land use classifications showed that sugarcane has expanded on 18,364.16 ha that were previously under agricultural use, which accounted for 91.43% of the sugarcane expansion area in Edéia. The next most common land use type that sugarcane expanded was native vegetation, at 1,356.95 ha, accounting for 6.67%. Pasture was the least common land use type covering 364.49 ha or 1.82% of the classified area.

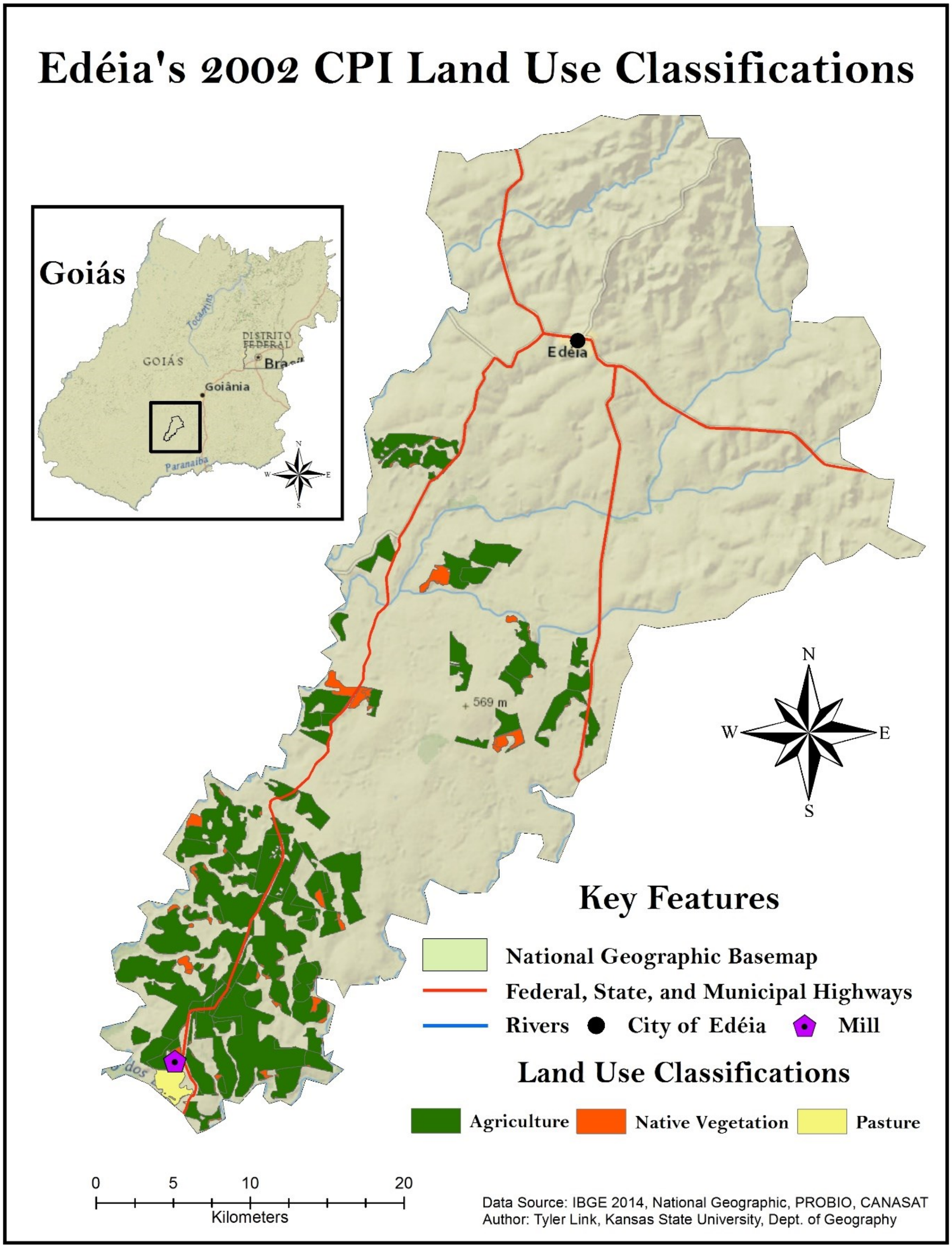


Figure 5.1 Edéia's 2002 CPI land use classifications

Table 5.1 Edéia's 2002 CPI land use classifications

Land use types	Hectares	Percentage of Total
Native Vegetation	1,356.95	6.76%
Agriculture	18,364.16	91.43%
Pasture	364.49	1.82%
Total	20,085.61	100%

Source: Canasat, PROBIO dataset

Nevertheless, CPI land use classifications allowed the identification of 12,261.1 ha of land in the three land use types for Caçu. The main land use type that sugarcane expanded on was pasture, accounting for 10,529.76 ha or 85.88% of the area classified. The next most prominent land use type that sugarcane expanded in Caçu was native vegetation, with 1,731.34 ha or 14.12% of the area.

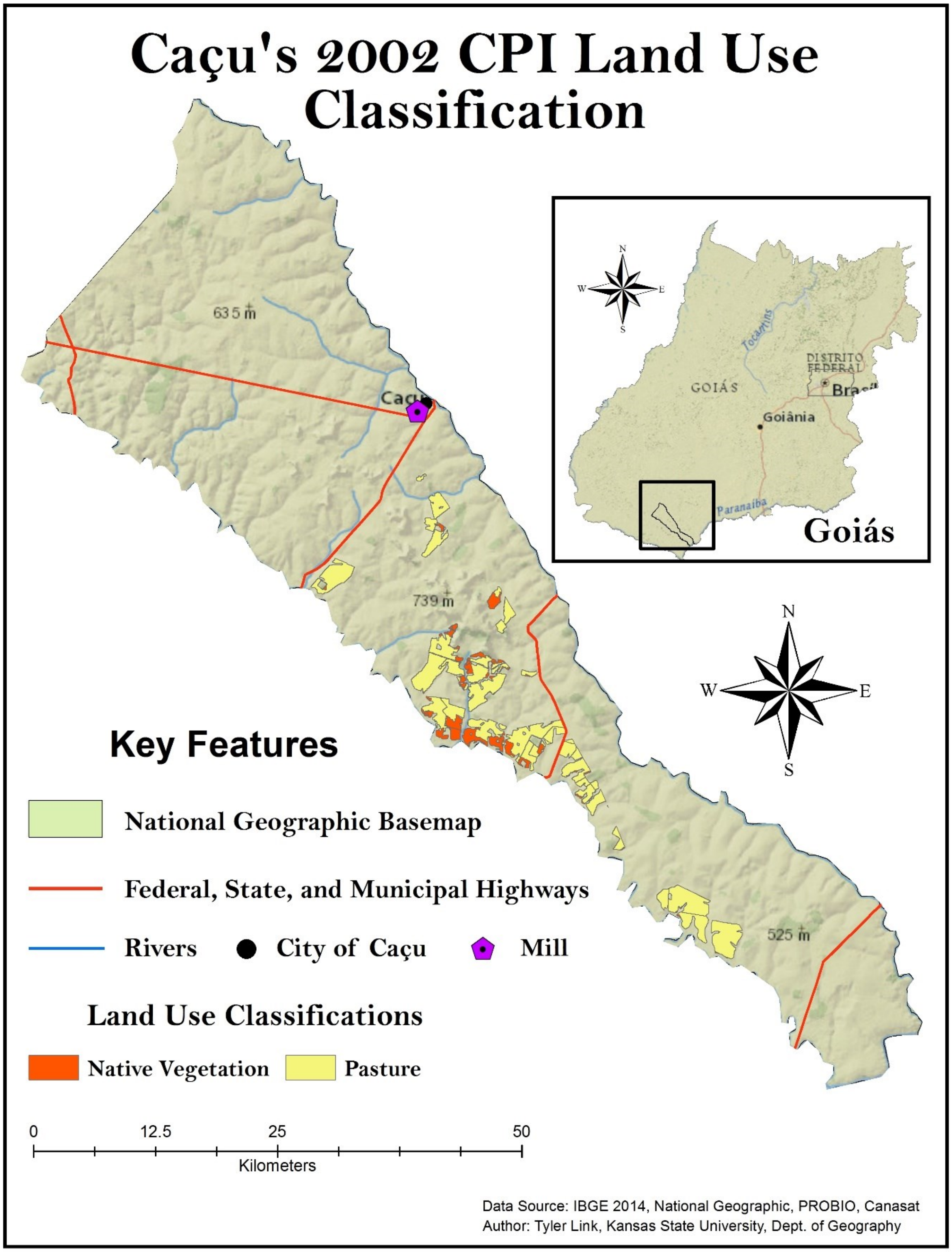


Figure 5.2 Caçu's 2002 CPI land use classifications

Table 5.2 Caçu's 2002 CPI land use classifications

Land use types	Hectares	Percentage of Total
Native Vegetation	1,731.34	14.12%
Agriculture	0.00	0.00%
Pasture	10,529.76	85.88%
Total	12,261.10	100%

Source: Canasat, PROBIO dataset

Quirinópolis, like Caçu, is in the transitional zone between the Cerrado and Atlantic forest biomes. Although only 23.79% of the 2012 Canasat polygons were covered by the PROBIO classification, it still accounted for 14,170.74 ha. The CPI land use classifications results for Quirinópolis were similar to the other two municipalities. The main similarity was that the majority of the sugarcane expansion had occurred on pasture, accounting for 11,293.46 ha or 79.7% of the area. The next most common area sugarcane had expanded on was agriculture on 2,217.01 ha or 15.64% of the area. Lastly, sugarcane expanded on just 660.26 ha of native vegetation or 4.66% of the expansion area

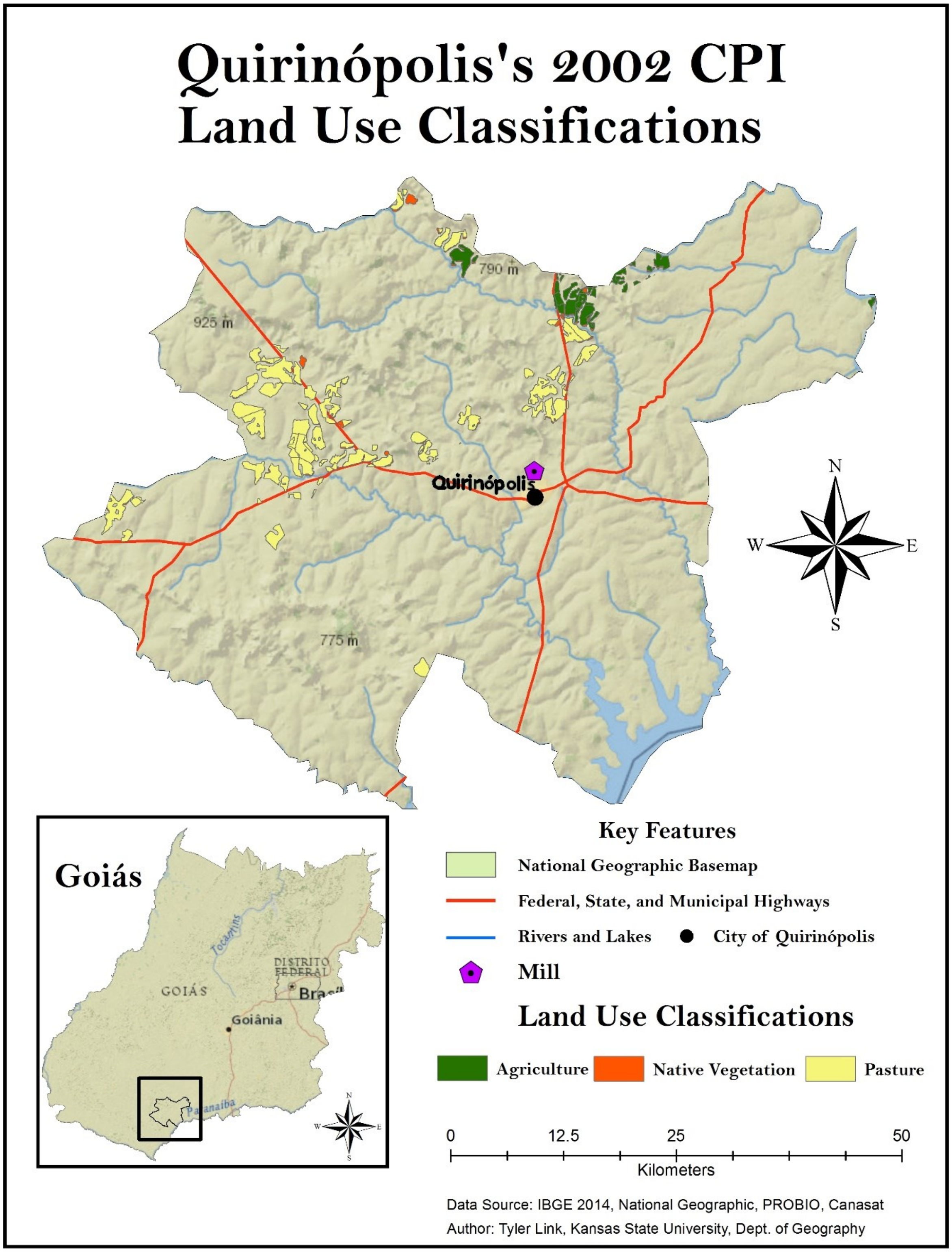


Figure 5.3 Quirinópolis's 2002 CPI land use classifications

Table 5.3 Quirinópolis's 2002 CPI land use classifications

Land use types	Hectares	Percentage of Total
Native Vegetation	660.26	4.66%
Agriculture	2,217.01	15.64%
Pasture	11,293.46	79.70%
Total	14,170.74	100%

Source: Canasat, PROBIO dataset

Since PROBIO dataset does not cover the entire 2012 Canasat sugarcane polygons there are concerns about the results. To overcome these concerns, I used the INPE time series tool to classify the previous land use intersection classifications in order to validate my findings (Figures 5.4, 5.5, 5.6, and Tables 5.4; 5.5; 5.6) (Freitas et al., 2011). The INPE time series tool represents a particular pixel of vegetation's change over time along the two-band Enhanced Vegetation Index (EVI2) that uses MODIS images from the MOD13, Q1 product (collection 5, 16 days composite, and spatial resolution of 250 m) (Jiang et al., 2008; Freitas et al., 2011). Therefore, the INPE time series tool uses MODIS imagery that has a much higher temporal resolution that can observe differences in vegetation over a long period of time compared to the PROBIO dataset, which uses LandsatETM+ that only takes one image every 16 days and may have frequent unusable imagery during the Cerrado's raining season due to cloud cover. In addition, it is important to note that the PROBIO dataset, although highly accurate, explained one major source of errors during their classifications. For instance, PROBIO dataset had difficulties separating pastures and crops, due to their similar spectral profiles during the Cerrado's dry season. In this context, the field level EVI2 spectral-temporal profiles that can obtain spectral profiles throughout the entire year may have an advantage over the PROBIO dataset that only used LandsatETM+ images from the Cerrado's dry season for this level of classification.

Consequently, using the INPE time series tool, the EVI2 land use classifications for Edéia were very similar to the CPI land use classifications. First, agriculture was the primary area of sugarcane expansion, taking 17,270.04 ha or nearly 86% of the sugarcane expansion area. Unlike the CPI land use classifications, pasture was the second most common land use type that sugarcane had expanded, totaling 1,608.66 ha or 8% of the sugarcane expansion area. Native vegetation covered 1,206.91 ha or 6% of the sugarcane expansion area. Overall, the majority of the sugarcane expansion has occurred on agricultural land just like the CPI land use classifications. The main difference in area size was related to the amount of pasture that sugarcane had expanded on.

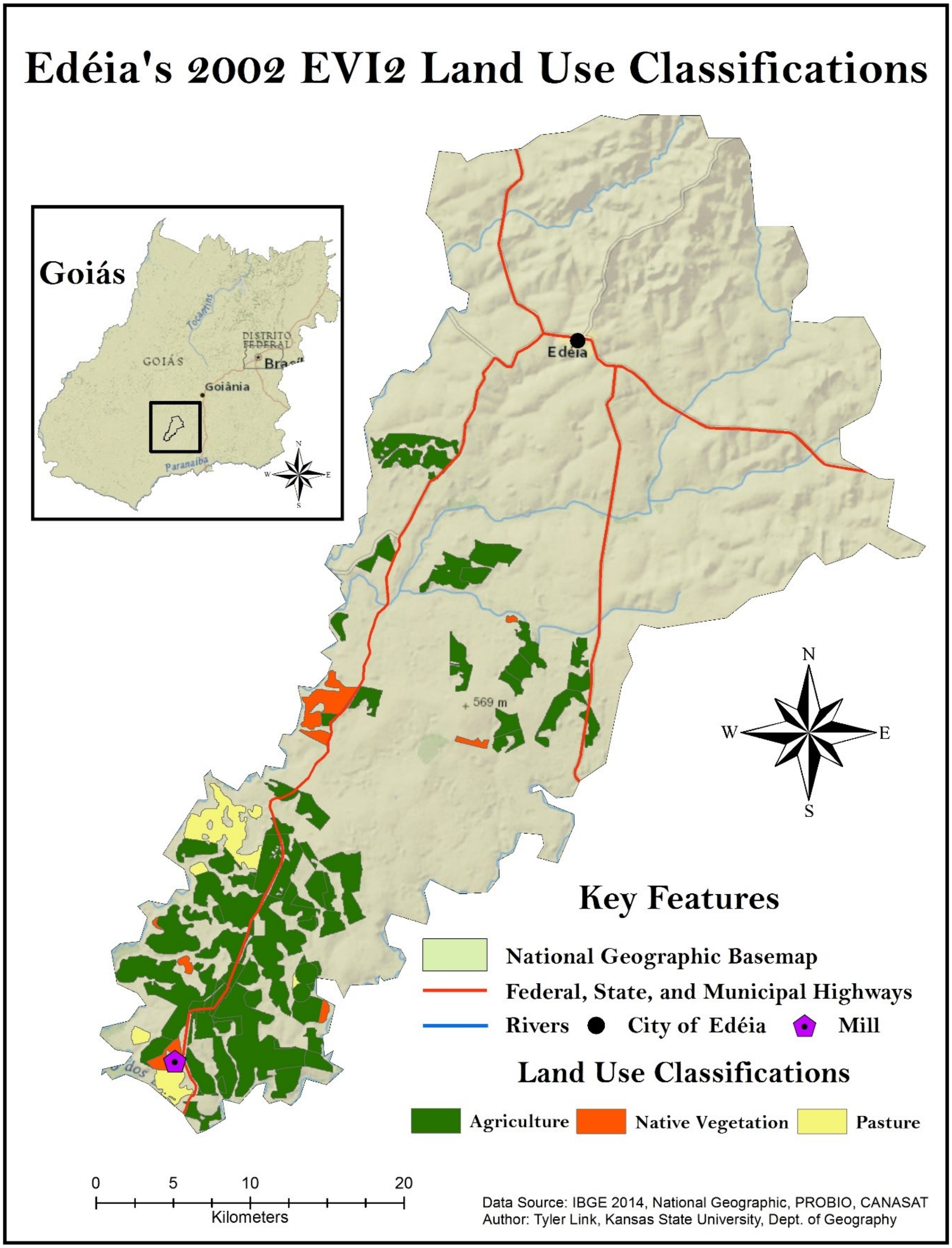


Figure 5.4 Edéia's 2002 EVI2 land use classifications

Table 5.4 Edéia's 2002 EVI2 land use classifications

Land use types	Hectares	Percentage of Total
Native Vegetation	1,206.91	6.01%
Agriculture	17,270.04	85.98%
Pasture	1,608.66	8.01%
Total	20,085.61	100%

Source: Canasat, PROBIO dataset

The EVI2 land use classifications validation used for Caçu was fairly similar to the CPI land use classifications. Like the CPI land use classifications, the predominate land use type sugarcane expanded on was pasture on 10,763.74 ha or nearly 88% of the entire area classified. Also, much like the CPI land use classifications, the EVI2 land use classifications validation found that native vegetation was the second most popular land use type that sugarcane had expanded on at 1,497.18 ha or 12.21% of the area classified. The EVI2 land use classifications validation was also very similar to the CPI land use classifications for agriculture, finding only 148.48 ha or just 0.5% of the area classified.

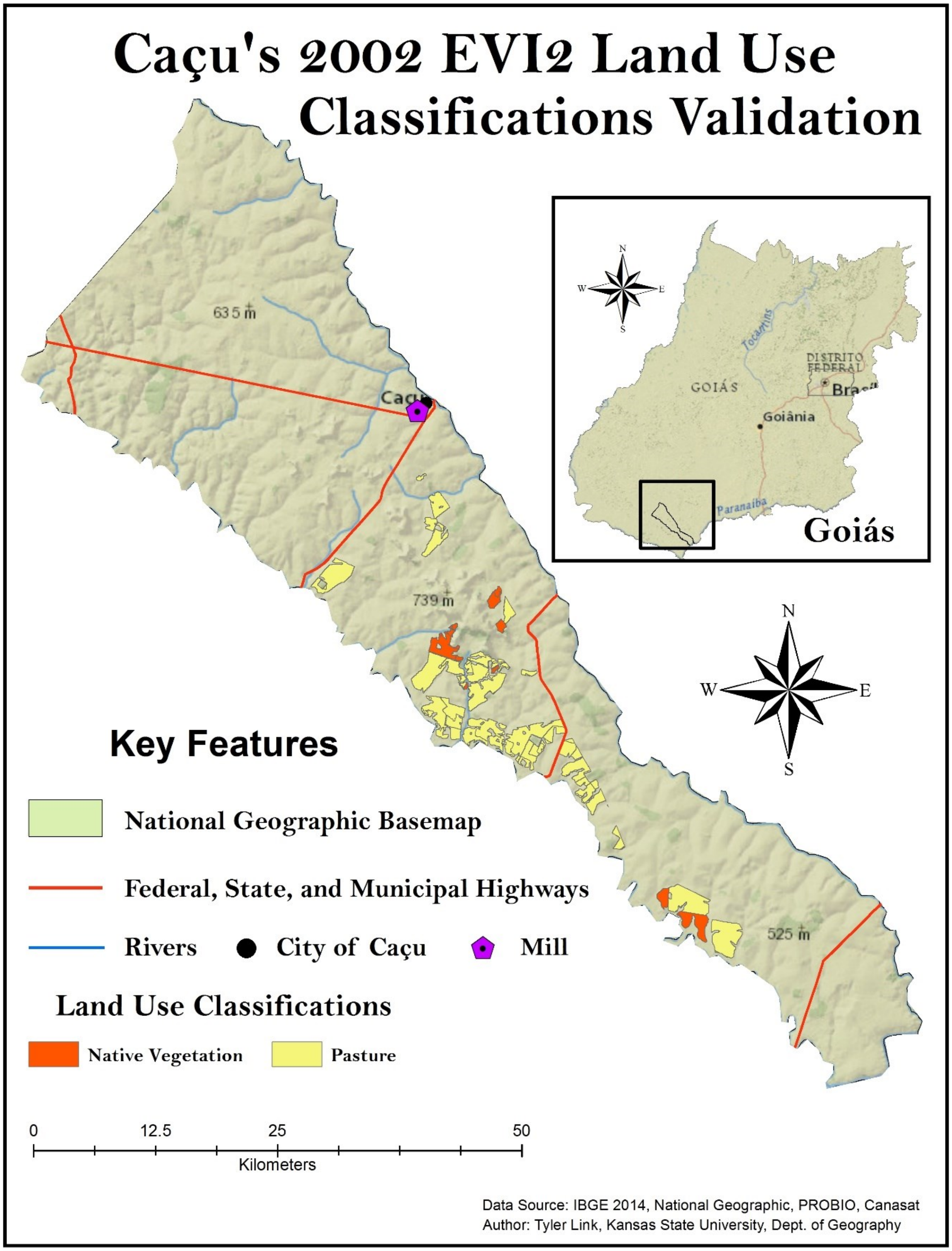


Figure 5.5 Caçu's 2002 EVI2 land use classifications validation

Table 5.5 Caçu's 2002 EVI2 land use classifications validation

Land use types	Hectares	Percentage of Total
Native Vegetation	1,497.18	12.21%
Agriculture	0.00	0.00%
Pasture	10,763.56	87.89%
Total	12,260.74	100%

Source: Canasat, PROBIO dataset, INPE

The EVI2 land use classifications validation for Quirinópolis had mixed compared to the CPI land use classifications. On one hand, native vegetation was very close in both classification methods. The EVI2 land use classifications validation found that sugarcane had expanded on 805.94 ha which was about 5.69% of the sugarcane expansion area. The major difference was classifying the agricultural use. The EVI2 land use classifications validation did not find as much sugarcane expansion on agriculture as the CPI land use classifications, only finding it had expanded on 443.04 ha accounting for just 3.13%. While pasture was the dominant land use type that sugarcane had expanded on accounting for 91.18% of the expansion, with a total of 12,905.61 ha. As noted above, the EVI2 land use classifications gives a more precise yearlong analysis of vegetation as opposed to the PROBIO dataset, which omitted that differentiating between agriculture and pasture was its biggest source of error.

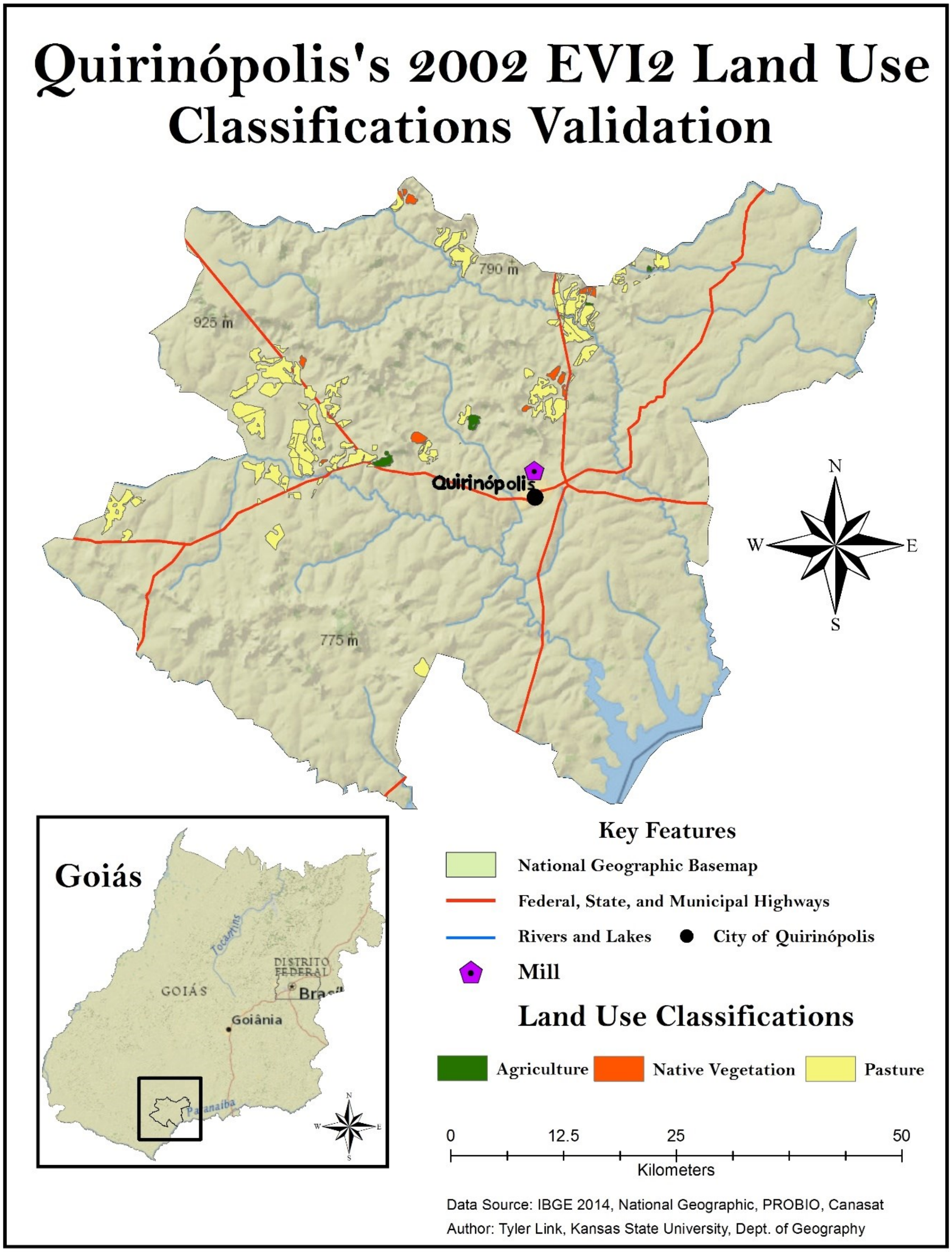


Figure 5.6 Quirinópolis's 2002 EVI2 land use classifications validation

Table 5.6 Quirinópolis's 2002 EVI2 land use classifications validation

Land use types	Hectares	Percentage of Total
Native Vegetation	805.94	5.69%
Agriculture	443.04	3.13%
Pasture	12,905.61	91.18%
Total	14,154.59	100%

Source: Canasat, PROBIO dataset, INPE

The results above gives confidence in expanding the EVI2 land use classifications to all of the 2012 Canasat sugarcane polygons. This involved using the INPE time series tool to classify the remaining 2012 Canasat sugarcane polygons that were not in the EVI2 land use classifications validation for the municipalities of Caçu and Quirinópolis. Edéia was completely covered by the EVI2 land use classifications validation, thus refer to Figure 5.4 and Table 5.4 for the complete EVI2 land use classifications.

The EVI2 land use classifications for the entire municipality of Caçu also gave some interesting results. The dominant land use type that sugarcane had expanded on was pasture, which accounted for 25,819.33 ha or 93.5% of the entire sugarcane expansion area. Next, native vegetation was classified covering 1,625.09 ha or 5.89% of the sugarcane area. Agriculture accounted for just 149.58 ha which measured to just half of a percent. Examining EVI2 land use classifications, EVI2 land use classifications validation, and the CPI land use classification, it is evident that the overwhelming majority of the expansion of sugarcane has occurred on pastures.

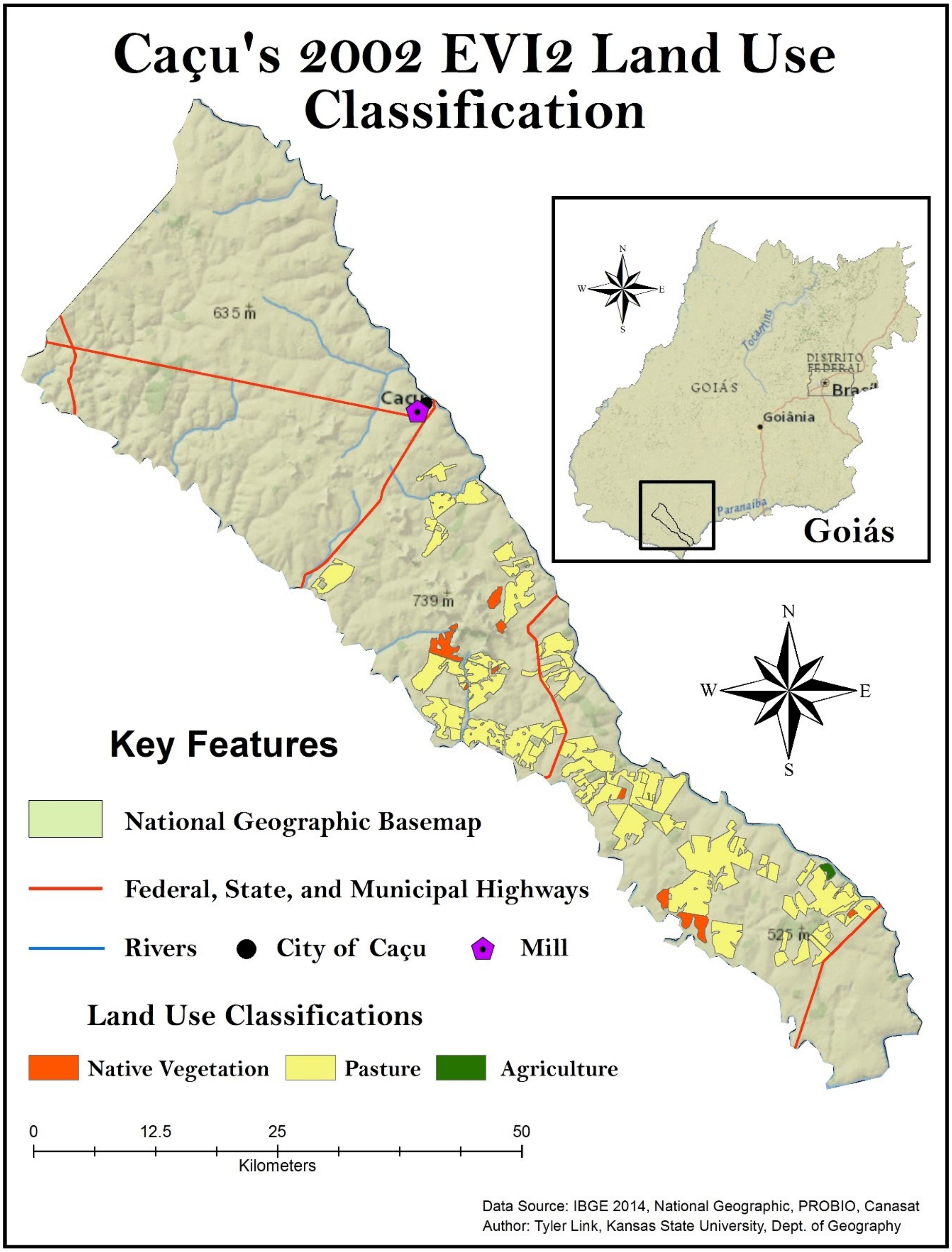


Figure 5.7 Caçu's 2002 EVI2 land use classifications

Table 5.7 Caçu's 2002 EVI2 land use classifications

Land use types	Hectares	Percentage of Total
Native Vegetation	1,625.09	5.89%
Agriculture	149.58	0.50%
Pasture	25,819.33	93.57%
Total	27,594.00	100%

Source: Canasat, PROBIO dataset, INPE

The EVI2 land use classifications for Quirinópolis brought mixed results. The most dominant land use type that sugarcane had expanded on was pasture accounting for 41,900.26 ha or 70.44% of the sugarcane expansion area. The next most common land use type of sugarcane expansion was agriculture, which had 16,392.55 ha or 27.59% of the entire coverage. The least common land use type that sugarcane had expanded on was native vegetation, which accounted for only 2% or 1,190.38 ha of the sugarcane expansion area. Comparing the EVI2 land use classifications with both the EVI2 land use classifications validation and the CPI land use classifications showcased that there were considerably more agricultural lands converted to sugarcane in the transitional zone between the Cerrado and the Atlantic forest.

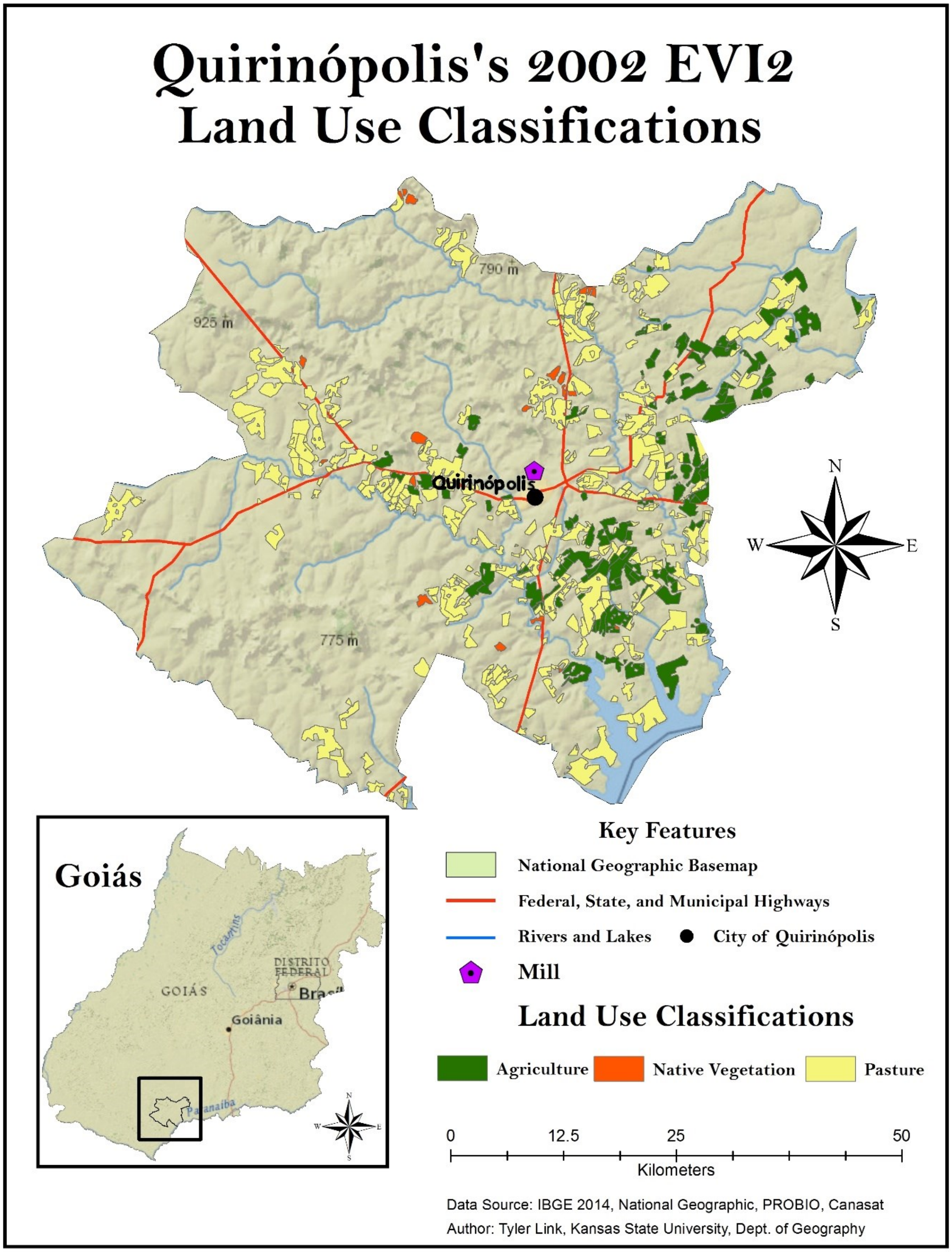


Figure 5.8 Quirinópolis's 2002 EVI2 land use classifications

Table 5.8 Quirinópolis's 2002 EVI2 land use classifications

Land use types	Hectares	Percentage of Total
Native Vegetation	1,190.38	2.00%
Agriculture	16,392.55	27.59%
Pasture	41,900.26	70.44%
Total	59,483.19	100%

Source: Canasat, PROBIO dataset, INPE

The results of sugarcane expansion from 2002 until 2012 varied across municipalities. Caçu and Quirinópolis found that the vast majority of lands that were converted to sugarcane came from pastures, which has been supported by other scholars in the region (Nassar et al., 2008; Rudorff et al., 2009; Adami et al., 2012; Novo et al., 2010; Pereira et al., 2012). Different from the other two municipalities, Edéia's land use was completely opposite of the other two municipalities, with over 85% of the prior land coming from agriculture. However, none of the three municipalities had large amounts of native vegetation being converted to sugarcane, with no municipality exceeding over 1,700 ha. Nonetheless, to understand how these municipalities' land use responded to the mills influence, an additional year was examined. This design was modeled after the research by Rudorff et al. (2009) that evaluated the direct land use conversion in response to increased sugarcane production in the Brazilian state of Paraná for 2000 and 2005. In order to see this transition for my study areas, I used data from the Brazilian Agricultural Census and the Canasat 2005 sugarcane polygons which indicated that two years prior to the start of sugarcane mill operations, which varied by municipality, each municipality had zero amounts of sugarcane planted. Understanding the immediate direct change in land use due to sugarcane mill starting operations is very important. The first municipality I will examine for this change is Edéia.

The results of the 2006 EVI2 land use classifications for Edéia were fairly consistent with the 2002 results, although had some minor changes. Agriculture, which was the largest land use type that sugarcane had expanded on in 2002, actually grew slightly to 17,887.17 ha or 89% of the sugarcane expansion area. These gains came mostly from pastures, which decreased to 1,125.55 ha or 5.6% of the sugarcane expansion area. Native vegetation also decreased in the area to 1,072.89 ha or 5.34% of the sugarcane expansion area. These results indicate that in Edéia, agriculture was the top land use prior to sugarcane both four and two years prior to the start of sugarcane mill operations.

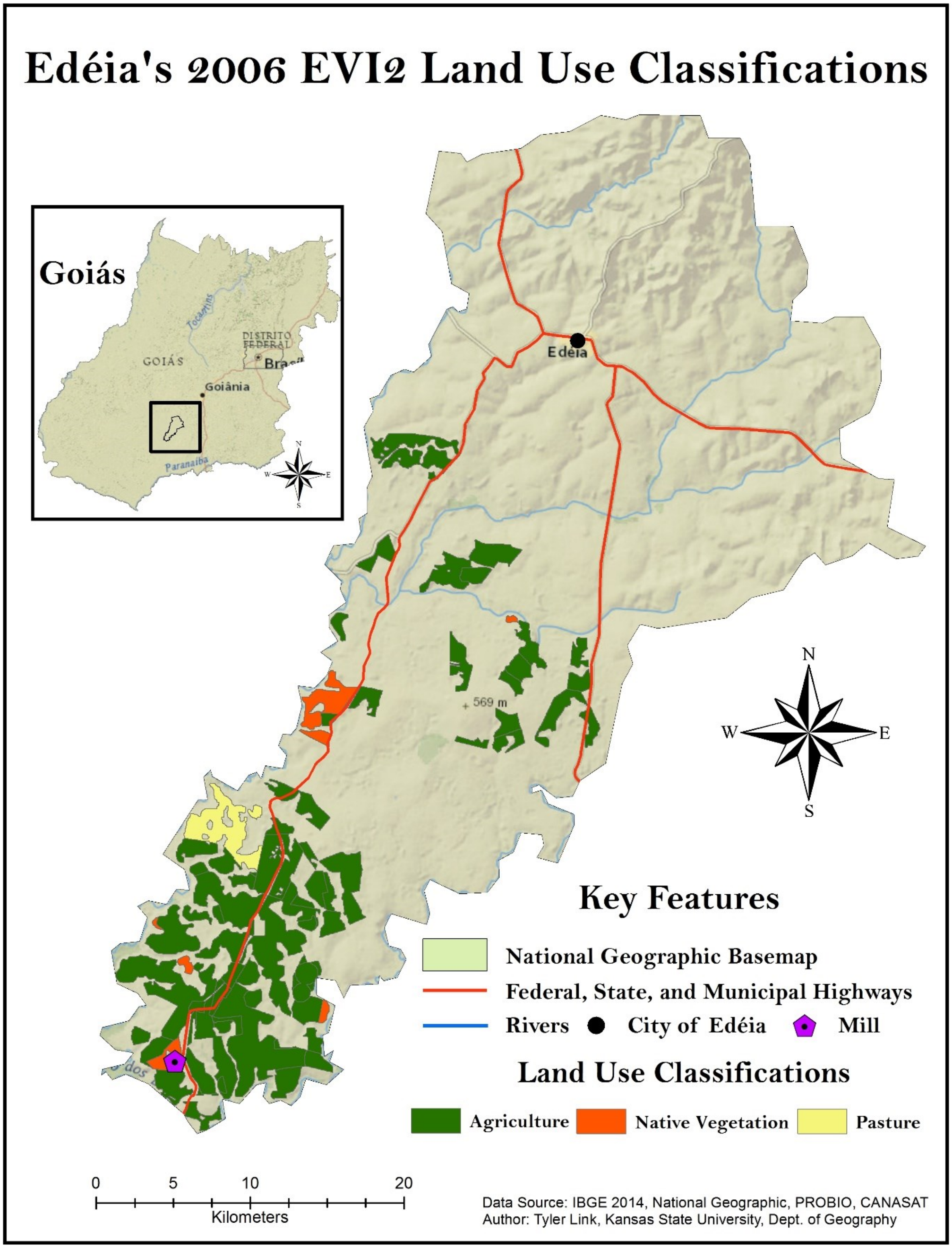


Figure 5.9 Edéia's 2006 EVI2 land use classifications

Table 5.9 Edéia's 2006 EVI2 land use classifications

Land use types	Hectares	Percentage of Total
Native Vegetation	1,072.89	5.34%
Agriculture	17,887.17	89.05%
Pasture	1,125.55	5.60%
Total	20,085.61	100%

Source: Canasat, PROBIO dataset, INPE

Much like Edéia, Caçu’s land use stayed fairly consistent from 2002 to 2007. Pasture remained the dominant land use type, encompassing 25,495.6 ha or 92.4% of the sugarcane expansion area. This was a slight drop from 2002 and most of this drop came from the growth of agriculture which grew to 588.78 ha or only 2.13% of the entire sugarcane expansion area. Native vegetation remained fairly consistent only decreasing slightly to 1,509.62 ha or 5.47% of the sugarcane expansion area. Overall, sugarcane expansion in Caçu came directly at the expense of pasture for both 2002 and 2007.

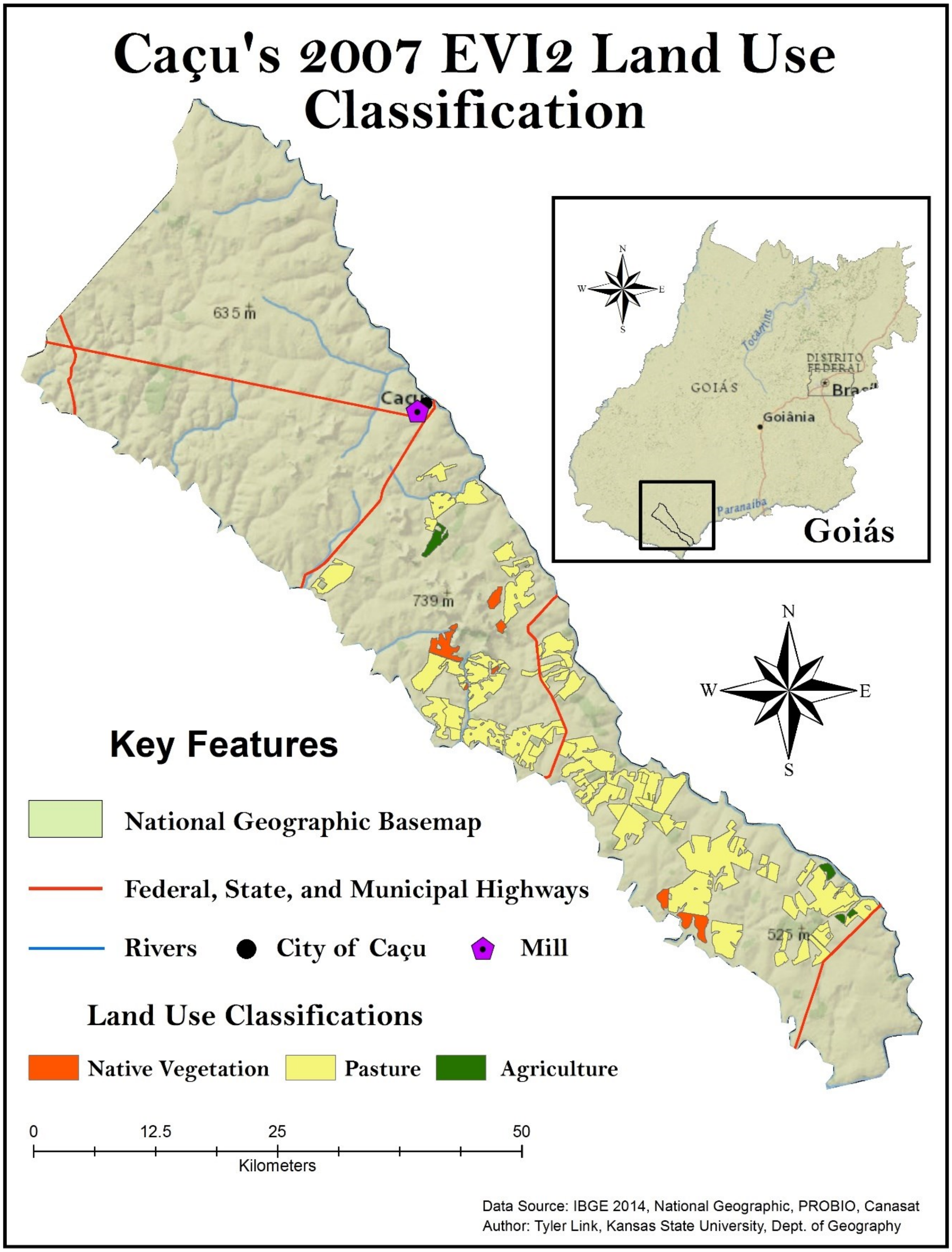


Figure 5.10 Caçu's 2007 EVI2 land use classifications

Table 5.10 Caçu's 2007 EVI2 land use classifications

Land use types	Hectares	Percentage of Total
Native Vegetation	1,509.62	5.47%
Agriculture	588.78	2.13%
Pasture	25,495.60	92.40%
Total	27,594.00	100%

Source: Canasat, PROBIO dataset, INPE

The most interesting results from the land use change analysis came from Quirinópolis transition from 2002 to 2005. There was a large transition from pasture to agriculture between these years. The amount of land used for agricultural crops grew over 10,000 ha to 27,007.85 ha by 2005 or 45.40% of the sugarcane expansion area. These gains were primarily at the expense of pasture, which decreased its land area by over 10,000 ha to 31,661.25 ha, accounting for 53.23% of the sugarcane expansion area. Native vegetation decreased its area slightly, by 2005 only 814.09 ha or 1.37% of the sugarcane expansion area. Although these results are interesting, they are not surprising. Rudorff et al. (2009) found similar results examining sugarcane expansion in the Brazilian state of Paraná, where the researchers used EVI/MODIS imagery from 2000 to 2008. They too used two base years for their research: 2000 and 2005. Rudorff et al. (2009) found in 2005 pasture accounted for 53% of the sugarcane expansion and annual crops accounted for 47%. However, examining the land use in 2000, they found entirely different results. In 2005, 25% of the land use classified as annual crops were pastures in 2000. This demonstrates the land use response to the increases in soybean prices during this time. This was also the case for Quirinópolis. Using the Brazilian agricultural census data also helps show this land use transition from 2002 to 2005.

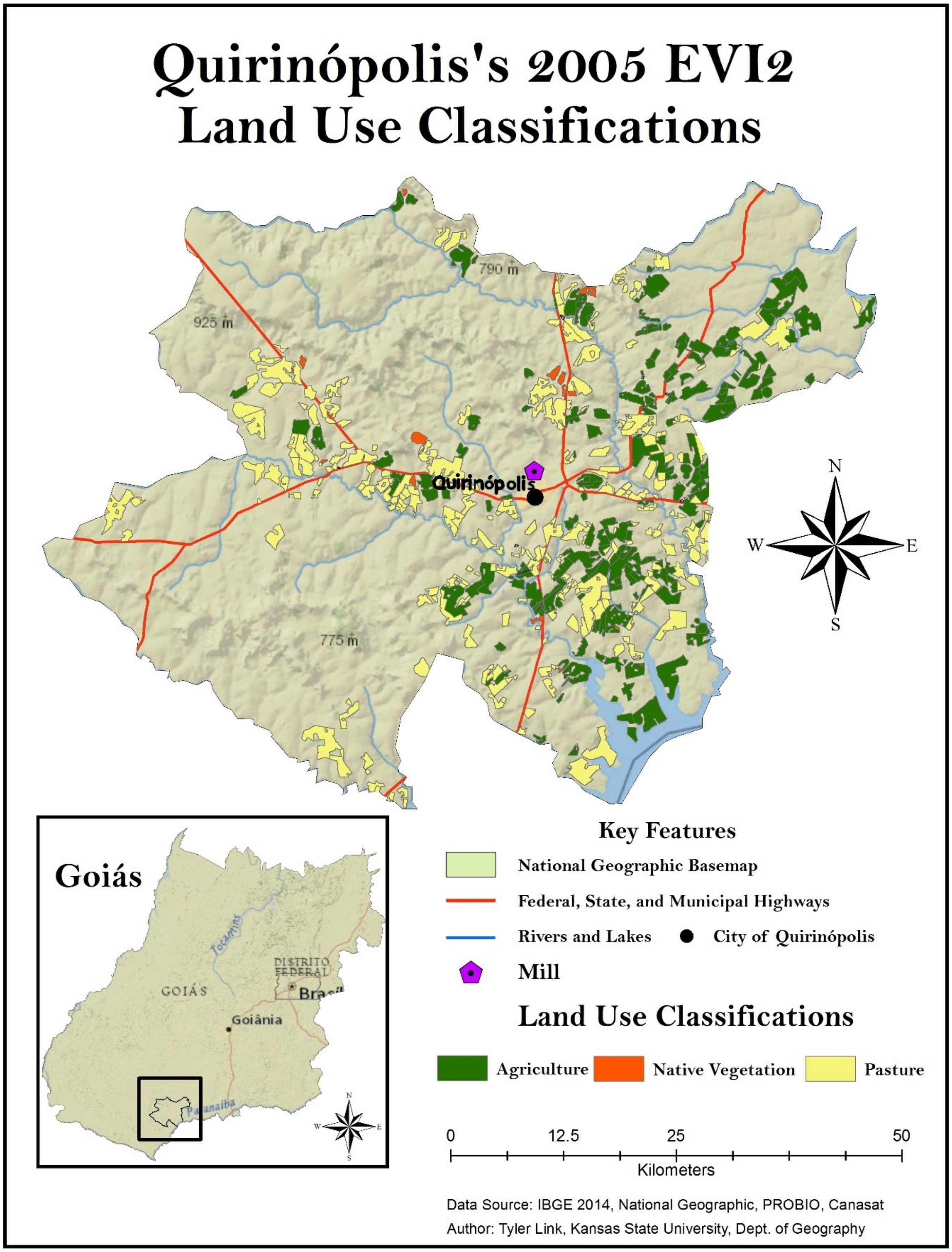


Figure 5.11 Quirinópolis's 2005 EVI2 land use classifications

Table 5.11 Quirinópolis's 2005 EVI2 land use classifications

Land use types	Hectares	Percentage of Total
Native Vegetation	814.09	1.37%
Agriculture	27,007.85	45.40%
Pasture	31,661.25	53.23%
Total	59,483.19	100%

Source: Canasat, PROBIO dataset, INPE

5.2 Trends in Goiás Agriculture: An Agricultural Census Analysis

In order to understand how sugarcane is changing the landscape of these municipalities, it is necessary to examine the agricultural census. Table 5.12 describes the transition of planted area in hectares (ha) and the number of cattle per municipality from 2002 to 2011 in all three municipalities. The period of analyze takes into consideration two years prior to the sugarcane mill starting operations. For instance, the year 2005 was selected for Quirinópolis due to the fact that the mill opened in 2007. The year of 2006 was selected for Edéia because the mill opened in 2008. The year 2007 was selected for Caçu because the mill opened in 2009. It is important to highlight that farmers have to plant sugarcane before the mill becomes operational, such that the crop will be ready for harvesting as soon as the plant is ready. This information, combined with the land use and land cover change analysis, helps to explain the expansion of sugarcane and its impacts on other crops and the cattle ranching throughout the study areas.

Table 5.12 also shows all the municipalities under study, there was no presence of sugarcane in 2002 or two years prior to the start of sugarcane mill operations. By 2011, the results show dramatic increases in sugarcane planted area. Quirinópolis, whose sugarcane ethanol mill started operations in 2007, had increased the planted area to 48,000 hectares (ha). Edéia, whose sugarcane mill opened a year later in 2008, also had a sizeable amount of sugarcane planted area with 15,860 ha. Caçu's sugarcane mill opened in 2009 and within two years had planted 7,431 ha of sugarcane.

This rapid expansion of sugarcane for all three municipalities had different impacts on the other type of crops grown in each area. Caçu's landscape consists of rolling hills, which may be a reason that transitional row crops are not as widespread in this area. The planted area of soy in Caçu, although it has grown over the past 10 years, is very small in area, accounting for only 600 ha in 2002 and 900 ha in 2011. In 2002, 2,000 ha of corn were planted, but by 2011 corn had decreased to only 400 ha. There was also a large decrease in area planted to rice; in 2002, 1,000 ha were planted and by 2011 the area had decreased to 300 ha. There were no cotton or beans planted in Caçu throughout this time period. There was not only a decrease in crops, but also the number of cattle[4]. In 2002, 208,247 head of cattle were in the municipality, but steadily decreased to 180,760 head by 2011. Thus, the relative small area planted to agricultural crops and the decrease of around 28,000 head of cattle from 2002 to 2007 helped verify this thesis EV2 land use classifications.

[4] This study is using number of cattle as a proxy for the area in pasture land. Data for pasture land is difficult to measure and obtain.

Table 5.12 Planted area by municipality (ha) and number of cattle per municipality for 2000 - 2011

Crop Type	Caçu				Edéia				Quirinópolis			
	2002	2007	2011	Trends	2002	2006	2011	Trends	2002	2005	2011	Trends
Sugarcane	0	0	7,431	Increasing	0	0	15,860	Increasing	0	0	48,000	Increasing
Soy	600	700	900	Increasing	46,000	57,800	40,000	Decreasing	30,000	37,000	20,000	Decreasing
Corn	2,000	300	400	Decreasing	2,050	2,000	2,800	Increasing	6,500	8,200	4,800	Decreasing
Cotton	0	0	0	Stable	3,310	360	0	Decreasing	151	84	0	Decreasing
Beans	0	0	0	Stable	120	83	0	Decreasing	1,050	250	0	Decreasing
Rice	1,000	250	300	Decreasing	200	300	200	Stable	810	2,000	100	Decreasing
Number of cattle	Caçu				Edéia				Quirinópolis			
	2002	2007	2011	Trends	2002	2006	2011	Trends	2002	2005	2011	Trends
Cattle	208,247	200,000	180,760	Decreasing	87,060	79,430	79,300	Decreasing	375,000	298,000	319,500	Decreasing

Source: IBGE Agricultural Census 2014

Edéia's terrain is much different than that of Caçu. The majority of the municipality has fairly even elevation and terrain, which makes row crop agriculture possible and efficient. This flatter landscape may be a reason why soy production was very attractive. In 2002, 46,000 ha of soy were planted, and that number increased to 57,000 ha in 2006. Although soy is still the dominant crop in the municipality, by 2011, just after three years of the sugarcane mill starting operations, the amount of area planted to soy had decreased to 40,000 ha. Among the other crops, it is possible to note that corn has grown slightly over the past decade, growing just 750 ha from 2002 to 2011. Also, 3,310 ha of cotton were planted in 2002, but this area decreased tremendously by 2006, and in 2011 there was no cotton being grown in the municipality. The next two crops examined are both important food staples in Brazil. First, beans whose planted area also decreased from 120 ha in 2002 to 0 ha in 2011. The other important food staple crop, rice, remained stable throughout the time period, with 200 ha planted in both 2002 and 2011. The number of cattle in Edéia decreased by nearly 8,000 from 2002 to 2011. Given that the area planted in soy for Edéia decreased about 17,000 ha from 2006 to 2011 and the area of sugarcane increased to 15,860 ha during this time helps validate the EVI2 land use classifications that found sugarcane was displacing agricultural crops more than pasture.

The final municipality that this thesis examined was Quirinópolis. Quirinópolis is a larger municipality than the first two, but it has similar land types. Quirinópolis' landscape is filled with rolling hills divided by river and stream valleys that crisscross the municipality and eventually flow into the São Simão reservoir along its southern border. Due to its diverse landscape, Quirinópolis also has a diverse variety of crops and land use types. In 2002, the largest crop in Quirinópolis was soy, which accounted for 30,000 ha and plateaued at 50,000 ha in 2004. However, the area planted in soy decreased to 20,000 ha by 2011. In addition, the trend is not different for other crops. For instance, corn also decreased in planted area accounting for 8,200 ha in 2005 to only 4,800 ha in 2011. Also, cotton decreased from 154 ha in 2002 to 0 ha in 2011. This trend was also true for beans and rice. In 2002, there were 1,050 ha of beans planted and by 2011 there were none at all. For rice, the planted area decreased from 810 ha in 2002 to 100 ha in 2011. Finally, the cattle herd for Quirinópolis also decreased. In 2002, the number of cattle was 375,000. By 2006, the cattle herd had decreased to 298,000 and eventually increasing to 319,500 head by 2011. This data helps validate the EVI2 land use classifications that also found a swift land use transition from 2002 to 2005.

5.3 Human Development Index and the Sugarcane Mills' Effect on Development

One of the goals of the study centers in understanding the effects of a sugarcane mill in the socioeconomic development of the municipalities. To accomplish this, I first looked at the Human Development Index (HDI) for the state of Goiás in comparison with the rest of Brazil (Table 5.13).

Table 5.13 Human Development Index (HDI) for the state of Goiás and Brazil

Indicators	Brazil			State of Goiás		
	1991	2000	2010	1991	2000	2010
Total HDI	0.493	0.612	0.727	0.487	0.615	0.735
HDI Income	0.647	0.692	0.739	0.633	0.686	0.742
HDI Longevity	0.662	0.727	0.816	0.668	0.773	0.827
HDI Education	0.279	0.456	0.637	0.273	0.439	0.646
Gini Index	0.63	0.64	0.6	0.59	0.6	0.55
Theil -L Index	0.78	0.76	0.68	0.61	0.65	0.53
*Infant Mortality	44.68	30.57	16.7	29.53	24.44	13.96
**Sanitation	66.97	76.72	87.16	65.06	86.07	93.66

Source: Atlas do Desenvolvimento Humano no Brasil 2013

* Infant mortality rate per 1,000 live births.

** Sanitation repersents the percentage of the population in households with piped water and toilets

The first indicator examined is the Total Human Development Index (HDI), in which the indicators for Goiás state were similar to the indicators for Brazil. In general, the HDI for Goiás rose from Very Low (below 0.5) in 1991 to High (0.7) over the two decades. Although Goiás is located in a less developed area of Brazil, when compared to the Southeast or South, it is possible to note that the HDI for income and longevity increased from Medium (0.6) in 1991 to High (0.70) for income and Very High (0.8) for longevity. Also, the HDI for Education has grown considerably throughout the Brazil and Goiás, starting at very low category in 1991, to eventually reaching the Medium category in 2010 with Goiás having higher level that the rest of the country. The Infant Mortality rate was an interesting indicator. Brazil had a much higher rate (44.68) than Goiás (29.53) in 1991. From 1991 to 2000 there were tremendous decreases in Infant Mortality rates. By 2010, the Infant Mortality rates were below 20 per 1,000 live births, with Goiás having the lower rate at 13.96.

The Sanitation indicator, which was calculated by the percentage of the population in households with piped water and toilets, also showed progress throughout Brazil. In particular Goiás showed excellent improvement; in 1991 only about 65% of its residents had access to sanitation, but by 2000, it had increased to about 86% and by 2010 it had increased to 93.66%, which was above the national average of 87.16%. The other two variables examined the inequality between these areas. Both the Gini Index and the Theil –L Index found inequality has decreased over the past 20 years, with the state of Goiás having inequality levels below the rest of the country. These results helped describe the socioeconomic development over the past 20 years for the entire country and most importantly, to the state of Goiás. By 2010, for all the indicators listed Goiás had higher socioeconomic development numbers than the country as a whole. After gaining this better understanding of the socioeconomic development for the Goiás, this thesis now turns its attention to the three municipalities' socioeconomic development over the same time period.

Table 5.14 examines the socioeconomic development over the past 20 years for the state of Goiás, and the three municipalities under study, Caçu, Edéia, and Quirinópolis. It is important to note that in the beginning of the 1990s the state of Goiás had human development index below the rest of the country, and more interesting is the fact that all these municipalities had total human development below the state index. However, all three municipalities and the state of Goiás, the Total MHDI has risen over the past 20 years. All of the municipalities and the state of Goiás started in the lowest development category of Very Low (below 0.5), but by 2000, all but Edéia, which rose to Low (0.5), grew to the Medium (0.6) category. From 2000 to 2010, all of the municipalities and the state of Goiás had risen within 0.05 of each other and now are located in the High (0.7) category on the MHDI scale.

The second variable under examination is the MHDI Income variable. For 1991, all the municipalities and the state of Goiás started in the Medium (0.6) category within 0.04 of one another. By 2000, there were modest increases in MHDI Income for all three municipalities and the state of Goiás and, in addition, all within 0.027 of one another. Then, by 2010 all of the municipalities and the state of Goiás had jumped into the High (0.7) category, with Caçu having the highest at 0.774 while Quirinópolis has the lowest at 0.732. Longevity also increased. In 1991, all but Caçu, who at 0.7 was at the lowest end of the High category, were located in the Medium category. By 2000, all the municipalities and the state of Goiás had risen to the upper levels of the High category. Then in 2010 again, all the municipalities and the state of Goiás had risen to Very High (0.8), with Quirinópolis having the highest value at 0.863 and Edéia the lowest at 0.826. Education levels were abysmal in 1991. With very low indexes for the state and the municipalities with Caçu having the lowest index. By 2000, the Education levels had risen dramatically, but all the municipalities and the state of Goiás remained in the Very Low (below 0.5) category. Most interesting was the change in education indexes between 2000 and 2010, in particular, Edéia. In 2000, Edéia had the lowest MHDI level of all the municipalities and the state of Goiás, but by 2010 it was the only municipality that had a MHDI Education level above the state of Goiás in 2010.

The Infant Mortality Rate per 1,000 live births indicator can give an idea of health changes. In 1991, all three municipalities had lower infant mortality rates than the entire state of Goiás. All the municipalities and the state of Goiás had Infant Mortality Rates 29.53 to 23.54 deaths per 1,000 live births. By 2000, the rates had gone down for each area, with the biggest decreases for Quirinópolis. The largest decreases in infant mortality occurred from 2000 to 2010, where each area decreased its infant mortality rate by about 10 deaths per 1,000 live births and all three municipalities had infant mortality rates below those of the state of Goiás.

Table 5.14 Municipal Human Development Index (MHDI)

Indicators	State of Goiás			Municipalities								
				Caçu			Edéia			Quirinópolis		
	1991	2000	2010	1991	2000	2010	1991	2000	2010	1991	2000	2010
Total MHDI	0.487	0.615	0.735	0.452	0.621	0.73	0.465	0.589	0.739	0.473	0.613	0.74
MHDI Income	0.633	0.686	0.742	0.655	0.68	0.774	0.621	0.676	0.755	0.617	0.659	0.732
MHDI Longevity	0.668	0.773	0.827	0.7	0.787	0.84	0.687	0.762	0.826	0.682	0.787	0.863
MHDI Education	0.273	0.439	0.646	0.201	0.448	0.599	0.236	0.397	0.648	0.251	0.445	0.642
Gini Index	0.59	0.6	0.55	0.62	0.58	0.53	0.61	0.59	0.53	0.57	0.55	0.46
Theil -L Index	0.61	0.65	0.53	0.7	0.57	0.5	0.66	0.61	0.48	0.58	0.51	0.36
*Infant Mortality	29.53	24.44	13.96	23.54	22.2	12.6	25.58	25.4	13.8	26.31	22.2	12.2
**Sanitation	65.06	86.07	93.66	71.27	92.1	98.36	59.15	91.72	98.52	70.63	91.04	97.52

Source: Atlas do Desenvolvimento Humano no Brasil 2013

* Infant mortality rate per 1,000 live births.

** Sanitation repersents the percentage of the population in households with piped water and toilets

Not different from the other indicators, over the past 20 years throughout the municipalities and the state of Goiás, sanitation has increased significantly. From 1991, there was a wide gap between Edéia, who had only 59.15% of households having access to toilets and piped water, and Caçu and Quirinópolis (71.27% and 70.63% respectively). The largest jump in the progress of sanitation for all occurred between 1991 and 2000. By 2010, all three municipalities had higher levels of sanitation than the state of Goiás, Edéia saw the greatest jump of all from 59.15% to 91.72%. The other two municipalities were also above 90%.

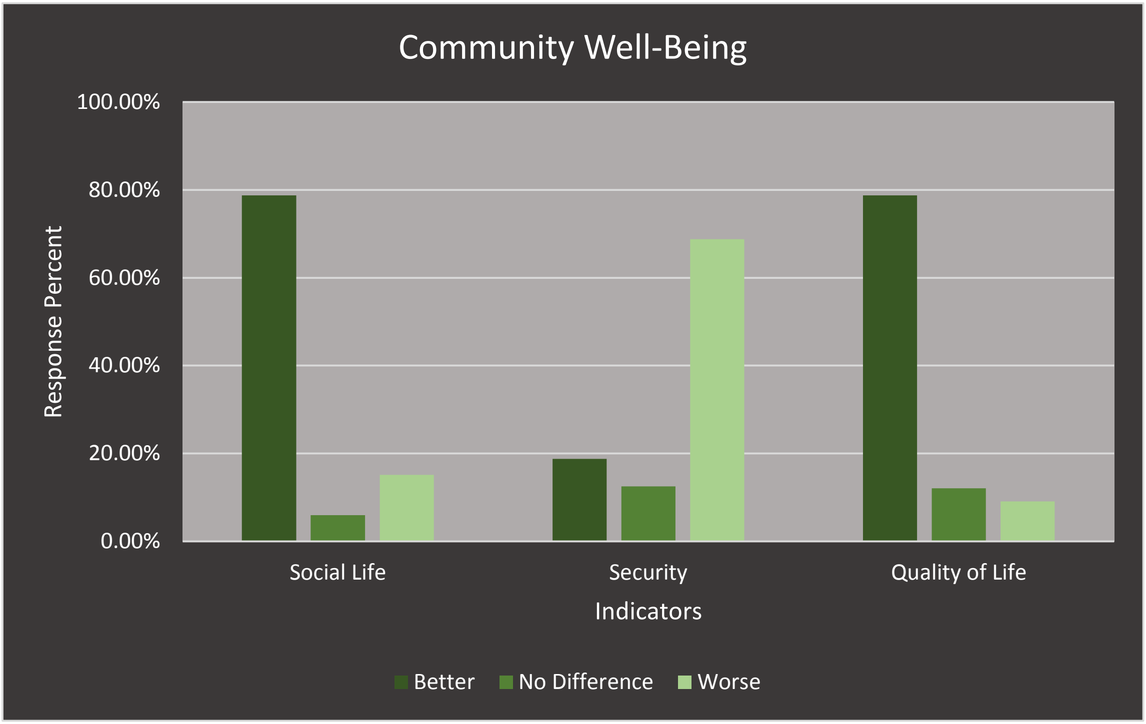
Since 1991, inequality has decreased. The largest decline in inequality occurred in the municipality of Quirinópolis. In 1991, the Gini Index was at 0.57 and by 2010 declined to 0.46. Both Caçu and Edéia were almost identical. In 1991, the starting Gini Index was 0.62 and 0.61 respectively. By 2010, it had decreased to 0.53 for both municipalities. The Theil – L Index found that the inequality within the municipalities was lower than for the state of Goiás. It is important to highlight that the most modest drop occurred for the state of Goiás where in 1991 the inequality was 0.61, eventually rising to 0.65 in 2000 and then dropping to 0.53 by 2010. Caçu in 1991 was the most unequal of all three municipalities at 0.7 but dropped down to 0.57 in 2000 and 0.5 by 2010. Edéia inequality was similar to Caçu in 1991 with the Theil – L Index at 0.66, dropping to 0.61 in 2000, and then to 0.48 for 2010. Quirinópolis Theil – L Index was the lowest for the entire time series with 0.58 in 1991, eventually dropping to 0.51 by 2000, then at 0.36 in 2010. In summary, the analysis shows that socioeconomic development has been occurring over the past twenty years throughout the state of Goiás and in the three municipalities under study.

To look at the role of the mills in the development of these municipalities, I interviewed both the farmers and city residents throughout the municipalities of Edéia, Caçu, and

Quirinópolis. These surveys were distributed with the intent of understanding how farmers and citizens of these municipalities perceive the sugarcane mills' impact on their communities' well-being.

Table 5.15 grouped the indicators of Social Life, Security, and Quality of Life into the Community Well-Being category. The results show that 78.79% of the farmers perceived that their Social Life and Quality of Life overwhelmingly improved after the sugarcane mills entered their respective communities. This was the case due to the increased number of bars a restaurants and the guaranteed financial incentives that came with having their lands under sugarcane contract with the mills. However, the most interesting indicator is Security, which a strong majority of farmers (68.75%) saying security had decreased compared to only 18.75% who claimed it had gotten better. Reasons for security concerns included dangerous dusty roads with large trucks that are used to transport the harvested sugarcane to the mills. In addition, the farmers perceived that the sugarcane mill had increased the number of automobile accidents, robberies, and assaults. This was largely due to the farmers perceiving that the new migrants coming from other regions of Brazil were considered outsiders and may not have trusted them

Figure 5.12 Famers' perceptions on Community Well-Being



Regarding health issues and education, Table 5.16 below grouped the indicators of Public Health, Private Health, and Education. The answers in this category were not as clear cut as the Community Well-Being category. In regards to Public Health, a slight majority noted improvement after the entry of the mill, with 24.24% claiming they perceived no differences and 27.27% stating it had gotten worse. Farmers' perception of Private Health are similar to Public Health, larger majority of farmers had stated that Private Health had improved after the sugarcane mill's arrival at (59.38%), with 21.88% perceiving no difference, and 18.75% claiming it had gotten worse. For Education, a slight majority (51.16%) claimed that the ethanol mill made no difference improving education standards in their municipalities. However, 38.71% said it had gotten better and only 9.68% claimed it had gotten worse.

Figure 5.13 Farmers' perceptions on Socioeconomic Development

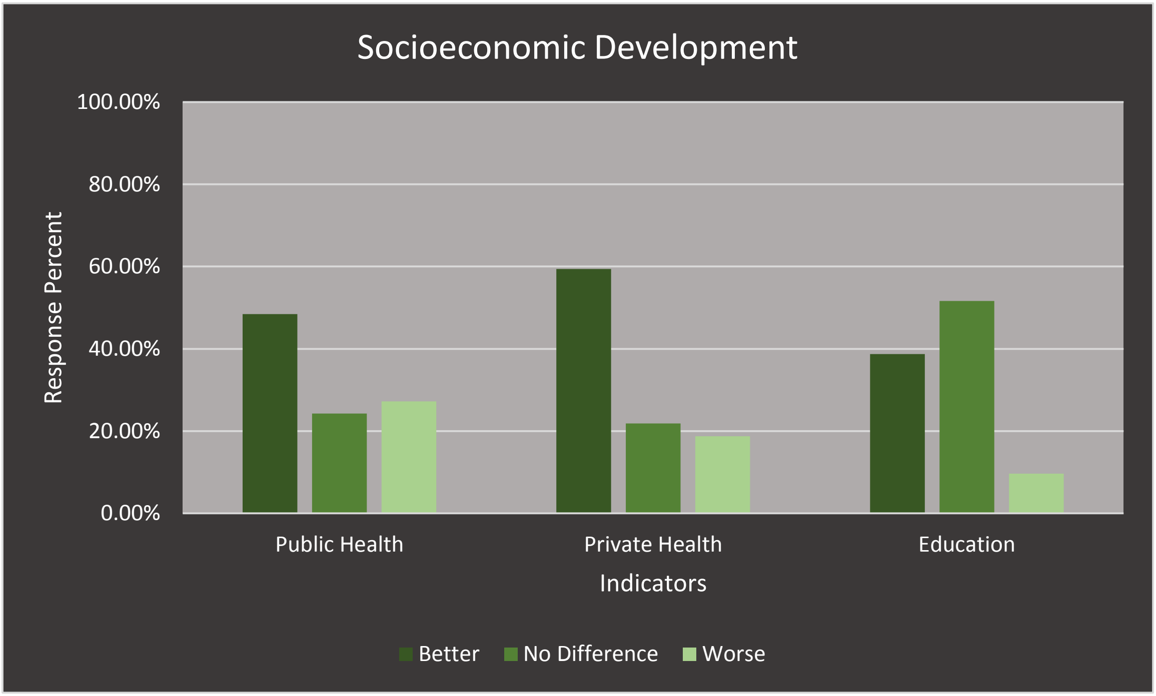
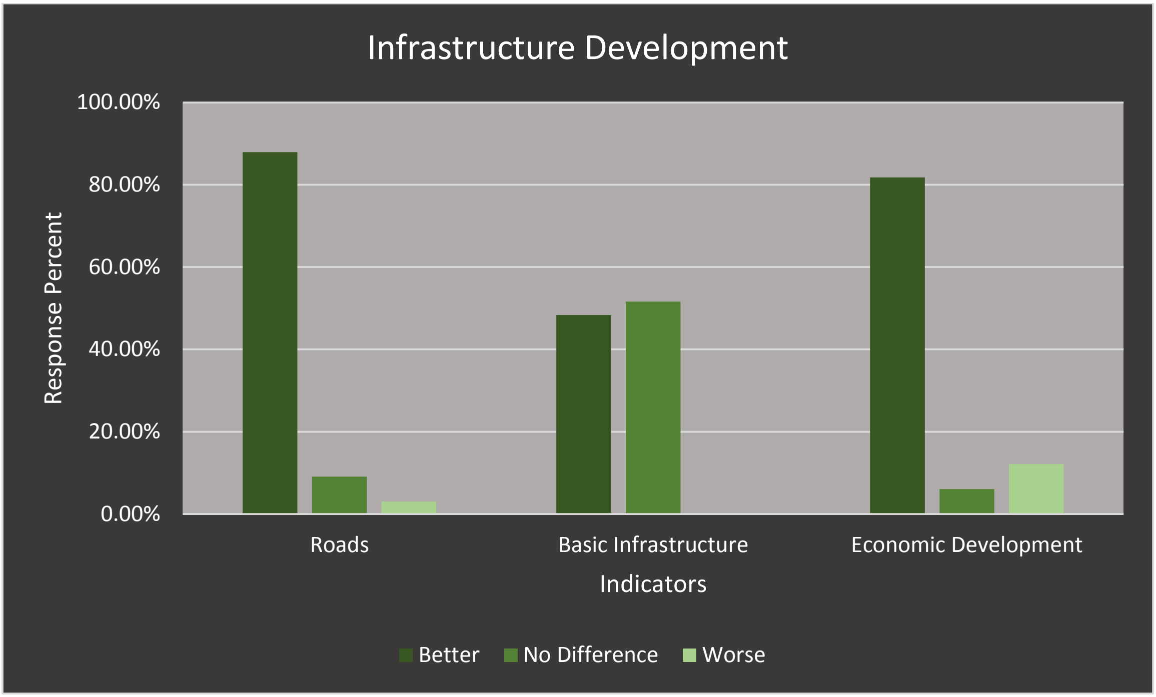


Table 5.17 evaluates farmers' perceptions on Roads, Basic Infrastructure, and Economic Development. An overwhelming 87.88% of farmers stated that Roads had improved after the introduction of the sugarcane mills whereas only 3% said they had gotten worse and 9.1% perceived there was no difference. The Basic Infrastructure indicator generally consisted of construction of waste management, street lighting, and affordable housing. Interesting to note that no farmers perceived that the Basic Infrastructure had gotten worse while a slight majority said there was no difference and 48.38% claimed that it had gotten better. The Economic Development indicator consisted of new business and jobs. Keeping this in mind, the Economic Development indicator was one sided. Almost 82% of farmers indicated that the sugarcane arrival in their municipality had brought economic development as oppose to about 6% that stated there was no difference and about 12% claiming that it had gotten worse.

Figure 5.14 Farmers' perceptions on Infrastructure Development



In all, farmers throughout the municipalities found that the sugarcane mills generally had a positive impact on their lives and communities. Social Life, Quality of Life, Roads, and Economic Development were the strongest positive indicators for the sugarcane mills' impact on their lives. Interesting to note that the Security indicator had a strong negative impact on their communities. The security concerns voiced by some of the farmers came from heavy traffic along dirt roads that caused dust to make driving more dangerous. Although the sample size was small, grouping all the famers' together may have masked some perceptions that we found from the field interviews. Where in many cases, informally farmers perceived that the foreign owned mills were more reliable than their domestic competitors.

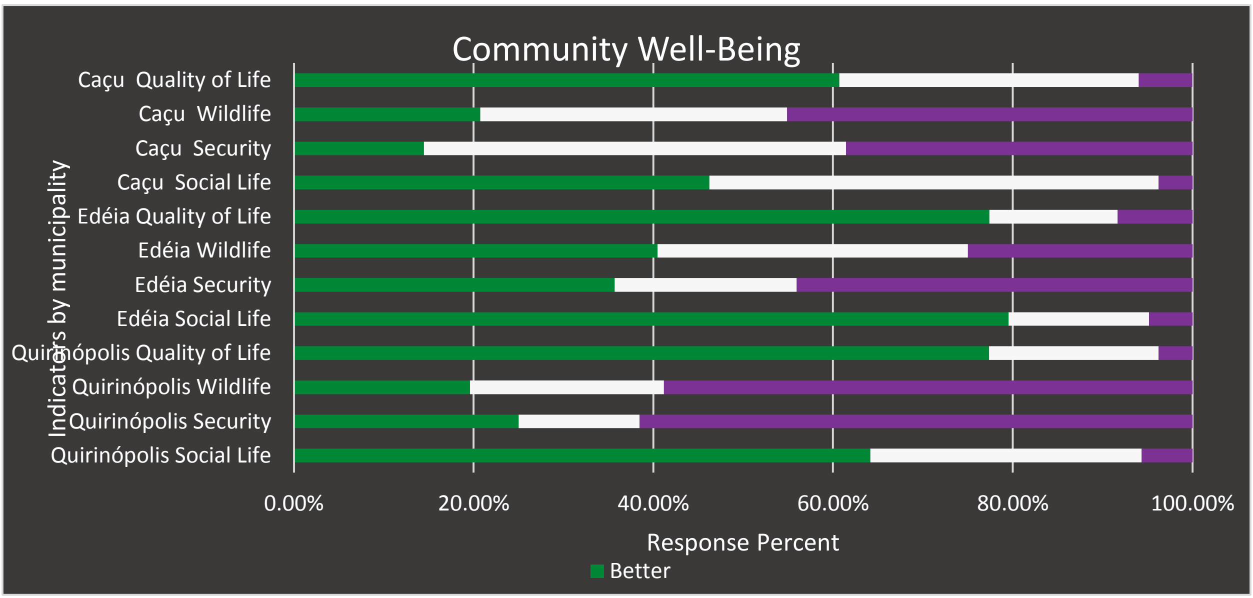
Communities in Goiás are not only composed of farmers, there are also urban residents. Thus, I evaluated the perceptions of urban residents about the construction of the mill in their city. The city survey indicators were grouped in the same fashion as the farm survey. There was one question added that was not on the farmers survey and that asked about the quality of Wildlife (e.g. quality of streams, rivers, and numbers of native animals) after the sugarcane mill arrived, and it was placed in the Community Well-Being category.

The Community Well-Being category had mixed results (Table 5.18). Edéia had 79.52% of the respondents' stating that Social Life (e.g. new bars, restaurants, and entertainment) had gotten better after the arrival of the sugarcane mill, while only 4.82% thought it had gotten worse and with 15.66% stating there was no difference. Quirinópolis had similar results with 64.15% of respondents confirming that Social Life had gotten better while 30.19% thought there was no difference and only 5.56% thought it had gotten worse. Caçu's Social Life respondents were different from the rest. Only 46.25% of respondents thought it had improved while the majority 47.62% saw no difference and only 3.57% thought it had gotten worse. It is important to highlight that Edéia and Caçu are very similar municipalities (e.g. area size, population). However, their perceptions on Social Life showed different results. A total of 61.54% of respondents in Quirinópolis thought that Security had gotten worse in their city. Edéia was more evenly distributed amongst the three options where 44.05% thought it had gotten worse, 35.71% thought it had gotten better and 20.24% said there was no difference. Caçu meanwhile had only 14.46% of responds agree that security had gotten better after the arrival of the mill, 46.99% found no difference and 38.55% found that it had gotten worse. This was interesting because both the farmers and residents from all three municipalities agreed that security did not get any better once the sugarcane mill came into their areas. Interesting to note that Edéia had more residents agree that security improved when compared to Caçu and Quirinópolis.

Perceptions on Wildlife (e.g. quality of rivers, numbers of native animals) varied greatly between all three municipalities. Quirinópolis had 58.82% of urban respondents stating that the quality of Wildlife had gotten worse after the introduction of the sugarcane mill, 21.57% said it was no different and 19.61% thought it had gotten better. Edéia was just the opposite, where 40.48% of respondents thought the quality of Wildlife had gotten better, 34.52% thought there was no difference, and 25% thought it had gotten worse. Caçu respondents were more mixed, where about 45.12% said that the quality of Wildlife had gotten worse, 34.15% said it hadn't changed, and 20.73% said it had gotten better. These results are interesting when considering the land use change analysis. Edéia land use change came mostly from lands that were traditional row crop agriculture as oppose to the other two municipalities that had higher levels of pastures being converted. Although pastures do not hold high levels of biodiversity, they produce lower levels of habitat fragmentation than agriculture, thus helps conserve more biodiversity (Carvalho et al., 2009). Residents of Caçu and Quirinópolis may have perceived the loss of pastures more damaging to the quality of Wildlife when compared to Edéia where sugarcane replaced lands that were already in agriculture.

Regarding the Quality of Life, the results of the urban residents survey show that the majority of the respondents believe that the arrival of the sugarcane mill improved their quality of life. Over 77% of the respondents in Quirinópolis thought that the sugarcane mill had made their Quality of Life better as oppose to 18.87% that stated that there was no difference with only 3.77% stating that it had worsened. The vast majority of respondents in Edéia also said that the sugarcane mills arrival had made their Quality of Life better at just above 77%. Only 14.29% perceived it made no difference and 8.33% said it made it worse. Caçu's respondents said that the sugarcane mill had made their Quality of Life better (60.71%). Only 5.95% of respondents thought it had made it worse and 33.33% said they saw no difference to their Quality of Life. Although all three municipalities' respondents perceived the sugarcane mill improved their quality of life, Caçu respondents were considerably less optimistic than the other two municipalities.

Figure 5.15 Urban residents' perceptions on Community Well-Being

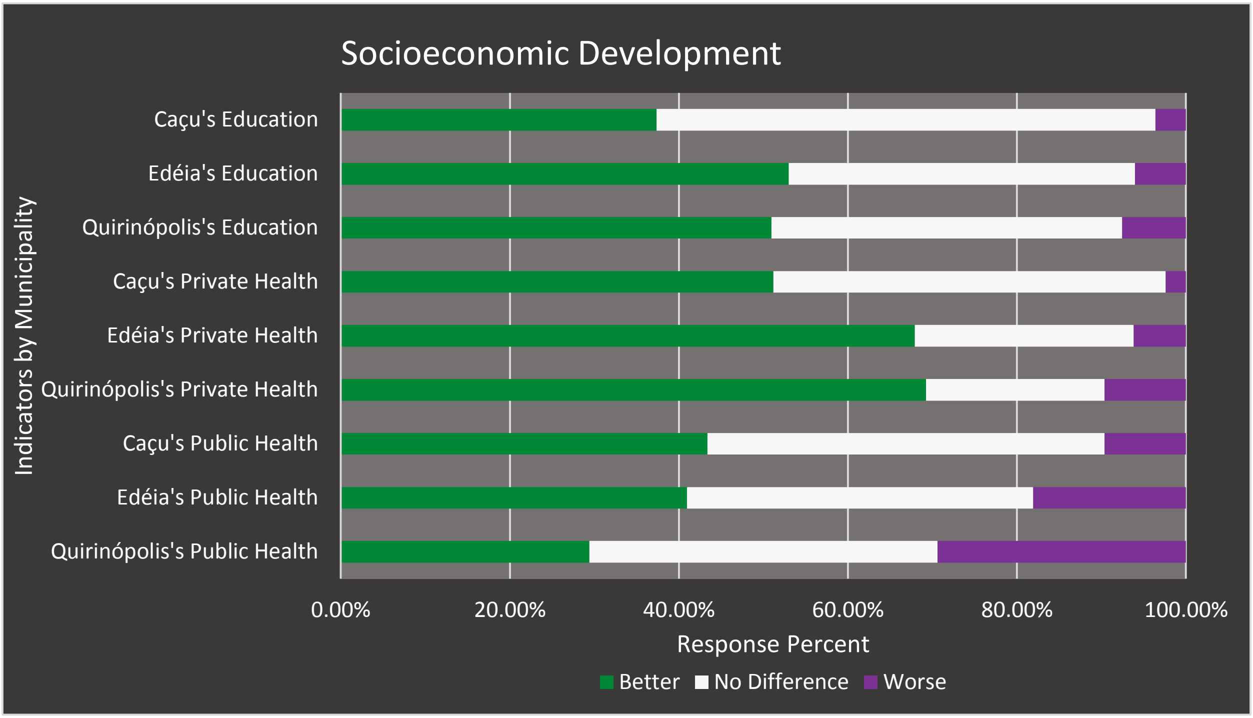


Like in the farmers survey, I examined the perception of the urban residents about improvements in the Public Health, Private Health, and Education in their municipalities after the after the arrival of the sugarcane mill (Table 5.19). Public Health (e.g. hospitals and doctors) perceptions were fairly consistent throughout the three municipalities, although only 29.41% of respondents in Quirinópolis said the Public Health had improved, compared to 40.96% for Edéia and 43.37% for Caçu. However, in general, it seems that there is a strong perception that Public Health didn't change after the mill. Private Health, just like the Public Health, perceptions were fairly consistent among the municipalities. Around 69% respondents in Quirinópolis said that

Private Health (e.g. dentists and eye doctors) had improved after the arrival of the sugarcane mill, 21.15% said there was no difference, and only 9.62% said it had worsened. This was also the case for Edéia with 67.9% of respondents thought that Private Health had gotten better, 25.93% respondents said it was no difference, and only 6.17% said it had gotten worse. The residents of Caçu did not think the arrival of the sugarcane mill had as much of an impact on Private Health as the other two municipalities. A slight majority of residents there thought it had improved (51.19%), 46.43% said it had stayed the same and only 2.38% thought it had gotten worse. Again, it is interesting to note that residents of Caçu did not perceive Private Health improve as much when compared to the other municipalities, but did fair better than the other two municipalities in the Public Health.

Education perceptions at the municipal level are similar. Edéia and Quirinópolis had close to half of their respondent's state that Education had gotten better while only 37.55% of respondents stated that for Caçu. Around 40% of respondents for Edéia and Quirinópolis and 58.33% for Caçu stated that Education was no different since the arrival of the sugarcane mill. Although these results were mixed, combining this survey information with the socioeconomic development indicators discussed earlier this chapter, found some interesting connections. Particularly for the municipalities Edéia and Caçu. From 2000 to 2010 Edéia greatly increased it MHDI for Education while Caçu had modest gains. This information, with the survey results, can help possibly show that the foreign-owned sugarcane mill in Edéia has brought better educational outcomes than the domestic sugarcane mill in Caçu.

Figure 5.16 Urban residents' perceptions on Socioeconomic Development

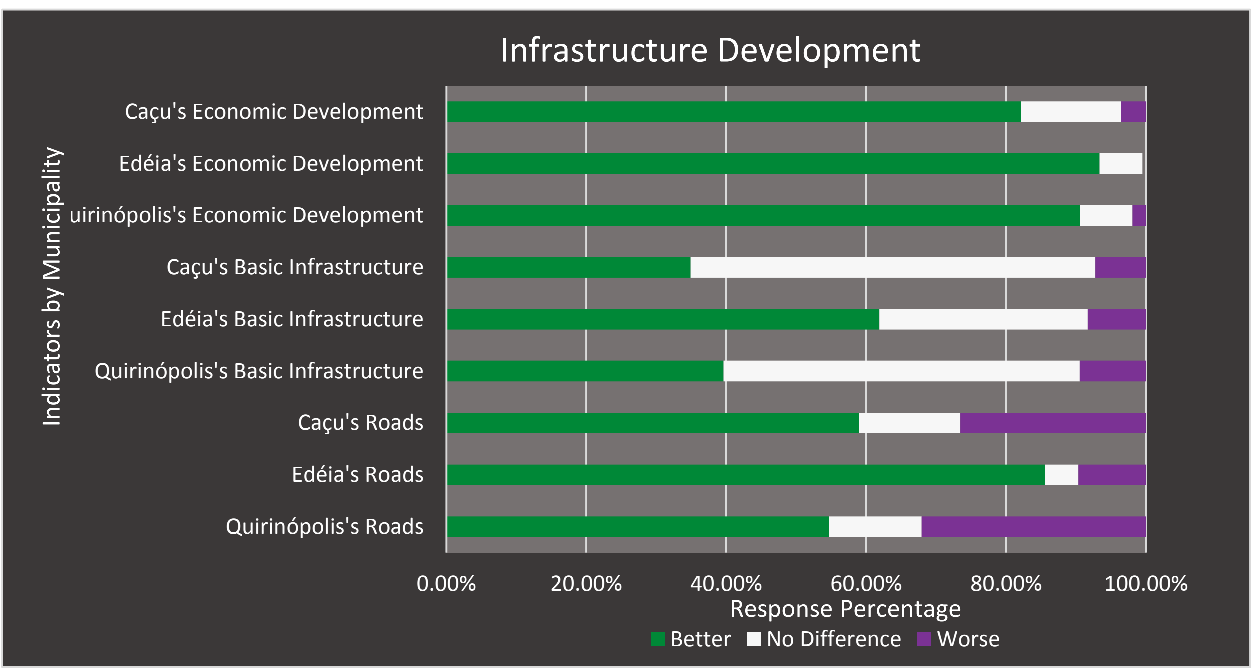


Urban residents' perceptions about Infrastructure Development shows that there were distinct differences between all three municipalities in how the different sugarcane mills impacted Infrastructure Development (Table 5.20). In general, 54.72% of respondents in Quirinópolis thought Roads had gotten better after the arrival of the sugarcane mill. While only 13.21% respondents thought there was no difference and with 32.08% stating that Roads had worsened. Caçu had similar results, where 59.04% of respondents said that Roads had gotten better, 14.46% said there was no difference, and 26.50% said that Roads had gotten worse. Edéia, on the other hand, was much different. Over 85% of respondents said that Roads had improved after the introduction of the sugarcane mill, with only 4.76% said that there was no difference and with 9.52% stating that Roads had gotten worse. The respondents of Edéia also thought that the Basic Infrastructure was better compared to the other two municipalities. Close to 62% of respondents thought that the Basic Infrastructure (e.g. waste management, street lighting, and affordable housing) had gotten better with 29.76% stating it was no different and 8.33% stating that it had gotten worse. Half of the respondents of Quirinópolis said that the Basic Infrastructure had stayed the same, 38.89% said it had gotten better, and only 9.26% perceived it had gotten worse. The respondents of Caçu were similar to those of Quirinópolis, where 57.14% stated that they perceived no difference in Basic Infrastructure while 34.52 claimed it was getting better and only 7.14% stated it had gotten worse.

In terms of Economic Development (e.g. new businesses and jobs) all the municipalities' urban respondents agreed that the arrival of the sugarcane was beneficial to their communities. Around 93% of the respondents in Edéia stated that they thought Economic Development had gotten better since the arrival of the sugarcane mill, only 6.10% stated that they saw no difference, and most interesting no one interviewed said that the economic development had gotten worse. Just over 90% of urban respondents in Quirinópolis said that Economic Development had gotten better after the arrival of the sugarcane mill, with 7.54% stated that they perceived no difference, and with only 1.89% of respondents believe it had gotten worse. Finally, 82.14% of the respondents from Caçu said that economic development had improved since the arrival of the sugarcane mill, with 14.29% stated they saw no difference, and with 3.57% said that it had gotten worse.

The results for Infrastructure Development category were interesting. The municipality of Edéia by far performed the best in this category, especially having much better positive responses for the quality of roads and basic infrastructure and no one interview there believed that the economic development had gotten worse. This may be due to the enormous amounts of investments entering the area. The comparison between Edéia, the foreign-owned sugarcane mill, and Caçu the domestic-owned sugarcane mill for the economic development was rather interesting. As discussed before, these two municipalities are extremely close in area and population size, and there are stark differences between the two municipalities' perceptions on Roads and Basic Infrastructure. This may be due to the large amounts of investments flooding into Edéia in recent years. In 2012, British Petroleum announced investing US$350 million into expanding its ethanol production capacity and Votorantim Cimentos (largest cement company in Brazil) announced investing US$300 million into building a cement factory only 20 miles away in the small town of Edealina (Bland, 2012; British Petroleum, 2012). There may be other reasons for such a difference, like city and municipal governance. The urban survey do show that the foreign-owned mill could be performing better than the domestically owned mill, and the jointly owned mill in terms of stimulating the economic development of these municipalities.

Figure 5.17 Urban residents' perceptions on Infrastructure Development



After examining all three categories within the city survey it was clear to see that the residents of Edéia perceived the sugarcane mill had brought better economic, socioeconomic, and better quality of life in general to their residents compared to the other two municipalities. While the resident of Caçu generally perceived that the benefits mentioned above were not necessarily as good and sometimes much worse than Edéia. While it was unclear why the residents of Quirinópolis perceptions of the sugarcane mill impacted their community were mixed of the three municipalities, which ironically what the ownership structure of the sugarcane mill there was.

It is important to remember that these two decades, Brazil went through a strong process of social development to become part of the BRICS (Brazil, Russia, India, China, and South Africa) emergent countries. To achieve this status, Brazil had a growing economy that allowed the development of many social programs that favored improvements in the quality of life of poor people. This expansion of social assistance programs first started under president Fernando Henrique Cardoso (1995-2002) but increased dramatically with the rise of the Workers' Party which came to power with president Lula in 2003 (Hall, 2006). Since then, poverty has been reduced by 55% from 35.8% of the population to 15.9% by 2012, while extreme poverty has been reduced even further, by 65% from 15.2% to 5.3 over the same time period. Overall the social assistance programs helped to lift 31.5 million people out of poverty and 16 million out of extreme poverty (Weisbrot & Lefebvre 2014). This was largely due to a government program called the *Bolsa Família* introduced by President Lula's Workers' Party. The *Bolsa Família* had two main objectives: first was to lower current poverty and inequality levels by implementing cash-transfer programs, and second to reduce future poverty and inequalities by investing in human capital like education (Lindert, 2006). The *Bolsa Família* greatly expanded on a previous cash-transfer program, and has grown from 4.8 billion Reais in 2003 to 20.7 billion Reais in 2012, making it the largest such program in the developing world (Lindert, 2005; Weisbrot &

Lefebvre 2014). The increase, in part, has been due to the number of individuals covered by the program. In 2003 only 16.2 million people were covered by *Bolsa Família*; this number grew to 44 million by 2006, and by 2012 it had increased to 57.8 million or roughly 29% of the population (Lindert, 2005; Weisbrot & Lefebvre 2014). Although critics of the *Bolsa Família* argued that it would decrease the participation in the workforce, participants in the program were 2.6% more likely to be working than non-participants (Oliveira et al. 2009).

One of the most popular cash-transfer programs under *Bolsa Família* was the *Bolsa Escola*. The *Bolsa Escola* program gave around US$7 a month to mothers whose children attended school at least 85% of the time (Hall, 2006). This attendance requirement has paid dividends as children in the program are 3.6% less likely to miss school, and have lower the dropout rates (Soares et al. 2007; Glewwe et al., 2012). The *Bolsa Escola* is one of the largest programs under the *Bolsa Família*, accounting for around half of its spending (Hall, 2006). In addition to the *Bolsa Escola,* the Brazilian government has increased its Educational spending. In 2000, Education spending represented 4.7 % of the nation's GDP, and by 2011 it had grown to 6.1% (Weisbrot & Lefebvre 2014).

The *Bolsa Família* transfers cash to households who earn less than R$120 per month with children up to 17 years old, or a pregnant woman with up to a maximum of three children. The program also transfers cash to individuals in extreme poverty amounting to R$60 per month as well as for extremely poor childless households (Hall, 2006; Soares et al. 2007). In addition, since 2004, Brazil has had a minimum wage guaranteed to all citizens which has predominately helped poorer workers (Soares et al. 2007). From 1995 to 2004 the Gini Index of inequality dropped by 4.7% with *Bolsa Família* responsible for 21% of that reduction (Soares et al. 2007).

Thus, the development of social programs in Brazil during the same period of time that the mills were built in the three municipalities reinforces the idea that although the sugarcane mills' arrival in these areas has brought increased jobs and infrastructure, it is impossible to separate these factors from the impacts of social programs from the Federal government.

Chapter 6 - Conclusion

As the world searches for alternatives to high priced and environmentally damaging petroleum fuels, biofuels have emerged as an attractive alternative. One biofuel in particular, Brazilian sugarcane ethanol, has many advantages over other biofuels throughout the world due to its lower carbon impact, high yield, and a large consumer market that was built with a long history of government support. These factors have helped sugarcane expand beyond the traditional regions of Brazil into the biodiversity rich but threatened Cerrado biome. Government led investments into agriculture technologies and infrastructure helped the Cerrado become an agricultural center for Brazil's important commodity crops and livestock. More recently, however, private capital both from domestic and foreign companies have started investing in Brazilian agriculture and these investments helped fuel the sugarcane expansion into the Cerrado in the last 15 years. The increased investments driving the expansion of sugarcane into the Cerrado brings numerous questions regarding its environmental and social impacts.

Thus, the goal of this thesis is to understand how the structural organization of the sugarcane ethanol mills' affects development at a municipality level in the state of Goiás, Brazil. More specifically, this thesis has two objectives: to evaluate the sugarcane mills' influence on land use and land cover change in these municipalities and to compare how domestically owned mills, foreign-owned mills, and jointly owned mills affect socioeconomic development on the municipalities.

Finding land use and land cover change results in the municipalities involved a multi-stepped approach that included fieldwork data collection and remote sensing analysis for the state of Goiás. This combination of techniques and methods allowed me to observe that although the mills had different ownership structures, the amount of native vegetation that sugarcane expanded on was very low compared to pasture and agriculture. That being said, it is plausible to say that the British Petroleum, the foreign-owned sugarcane mill in Edéia, expanded its operations at the expense of lands that were in agricultural use, in particular, soy. While Odebrecht, the domestically owned sugarcane mill of Caçu, expanded its operations on areas that were predominately from pastures. Quirinópolis, whose sugarcane mill SJC Bioenergy, was jointly owned by Cargill and Groupo USJ, first saw sugarcane expand on lands that were predominately pasture in 2002. However, by 2005, as a result of increased soy prices, agriculture expanded by 17.82%, on what was previously pasture. It is important to remember that Edéia had abundant flat terrain, perfect for large scale agriculture while Caçu terrain was hillier, thus pastures dominate the municipality. Quirinópolis (albeit a large municipality) was diverse, with both lands suited for pastures and for agriculture. One could argue that British Petroleum viewed Edéia's strong history of modernized agricultural and flat terrain as a perfect location to build their sugarcane mill, due to the increased concerns over manual harvesting's impacts on laborers and the environment.

The second objective seeks to compare how domestically owned mills, foreign-owned mills, and jointly owned mills affect socioeconomic development on the municipalities. Drawing from socioeconomic data compiled from the *Atlas do Desenvolvimento Humano no Brasil* showed that both Brazil and Goiás and all three municipalities showed increases in their socioeconomic development throughout the time frame. Between Brazil and Goiás and all three municipalities the differences in socioeconomic development were not significant. However, other occurrences within Brazil, including social assistance programs that helped millions rise out of poverty and the large growth of the Brazilian economy make it difficult to separate the sugarcane mills' impact on socioeconomic development.

This thesis also collected survey data to discover the perceptions of the sugarcane mills impact on the lives of farmers and city residents in my study area. A large majority of farmers throughout the study areas believed that social life, quality of life, roads, and economic development were better after the arrival of the sugarcane mill, while a smaller majority perceived both private and public health had also gotten better, although farmers have perceived that security had gotten worse. Security concerns were also the case for the respondents from the urban settings. Both farmers and city residents surveyed listed numerous reasons for their security concerns including: heavy traffic along dirt roads creating low visibility due to dust, and the influx of migrant workers that they perceived increased the rates of traffic accidents and burglaries. The urban respondents were fairly consistent in their belief that the sugarcane mills had brought economic development to their municipalities. The main conclusions from the city survey found respondents of Edéia perceived that the sugarcane mill had made their lives better than the respondents in either Quirinópolis or Caçu. In particular, the residents of Caçu generally perceived the sugarcane mill to have very little positive or no difference on their lives, while the residents of Quirinópolis had mixed perceptions over sugarcane mills impact on their lives

In summary, this thesis helps to understand how the rapid expansion of sugarcane has impacted the land use land cover change and development in the Cerrado. However, this analysis covers only a brief period of time, and future analysis of these, and other municipalities that host sugarcane mills throughout the Cerrado will be needed.

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